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Cancer Risk from Outdoor Exposure to Air Toxics
Volume 2. Appendices

Pacific Environmental Services, Inc., Durham, NC

Prepared for:

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16. ABSTRACT

This report presents an analysis of cancer risks in the United States from outdoor exposures to airborne toxic pollutants. It is intended to provide updated information to suggest priorities for air toxics control. This study is an update of an EPA report issued in 1985 entitled The Air Toxics Problem in the United States: An Analysis of Cancer Risks for Selected Pollutants (EPA-450/1-85-001, May 1985), known as the "Six-Month Study."

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This analysis is based primarily on information derived from recent studies and reports. Results are expressed as cancer risk from individual pollutants and source categories in terms of excess lifetime individual cancer risks and nationwide annual cancer cases.

Health risks due to indoor exposure and noncancer health effects resulting from outdoor exposure are not included in this analysis, but are addressed in separate studies.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
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CANCER RISK FROM OUTDOOR EXPOSURE TO AIR TOXICS

Volume II: Appendices

Final Report

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Cancer Risk from Outdoor Exposure to Air Toxics

VOLUME II: APPENDICES

FINAL REPORT

Appendix A.	Comments Received on the External Review Draft
Appendix B.	Cancer Risk Reduction Analysis for Selected Pollutants
Appendix C.	Summaries of Pollutant-Specific and Source-Specific Studies (Including Noncancer Health Risk Project on Air Toxics)

APPENDIX A

COMMENTS RECEIVED ON THE EXTERNAL REVIEW DRAFT

Approximately 23 comment letters were received on the September, 1989, external review draft of this report. Commenters included EPA personnel, industry representatives, State and local agencies, and university professors. Table A-1 lists the commenters and their affiliations.

The comments were tabulated and sorted by subject areas. The EPA then reviewed the comments to determine which ones would be incorporated into the final report. The following paragraphs summarize how EPA responded to some of the major comments.

Reference Section

Several commenters suggested that a reference section be added to both Volume I and Volume II. While separate reference sections were not created, we agree that more complete referencing was needed. In Volume I and Appendix B (Volume II), references are provided as they occur. In Appendix C, references are provided at the end of each summary.

Along similar lines, we have improved the citations within the report to facilitate access to source material for the reader. We have also increased cross-referencing within the report, particularly in Chapter 4, to facilitate the location of related information.

Glossary

Several commenters suggested that, to improve the readability of the report, a more complete glossary be provided, that a list of acronyms be provided, and that these be placed in Volume I, rather than as appendices in Volume II. We agree that these suggestions improve the readability of the report, and have incorporated them in Volume I of the final report.

TABLE A-1

LIST OF COMMENTERS

Commenter	Affiliation
Donald J. Ames	Stationary Source Division, California Air Resources Board
Walter J. Bishop	East Bay Municipal Utility District
Geraldine V. Cox	Chemical Manufacturers Association
Robert Fegley	U.S. EPA, Air Economics Branch
John L. Festa Robert C. Kaufman	American Paper Institute
Maryann Froehlich	U.S. EPA, Regulatory Integration Division
John Graham	School of Public Health, Harvard University
William Groah	Hardwood Plywood Manufacturers Association
Richard Guimond	U.S. EPA, Office of Radiation Programs
Charles E. Holmes	Department of Air Pollution Control, Commonwealth of Virginia
Stacey Katz	U.S EPA, Office of Technology Transfer and Regulatory Support
Steven D. Lutkenhoff	U.S. EPA, Environmental Criteria and Assessment Office.
Bruce K. Maillet	Division of Air Quality Control, Commonwealth of Massachusetts
William H. McCredie	National Particleboard Association
John F. Murray	The Formaldehyde Institute, Inc
John E. Pinkerton	National Council of the Paper Industry for Air and Stream Improvement, Inc.
John Roberts	Engineering Plus, Inc.
Robert R. Romano	Chemical Manufacturers Association

TABLE A-1

LIST OF COMMENTERS (concluded)

Commenter	Affiliation
Sara D. Schotland	Cleary, Gotlieb, Steen, & Hamilton
James H. Southerland	U.S. EPA, Pollutant Characterization Section
Donald F. Theiler	Department of Natural Resources, State of Wisconsin
Dr. Paul Urone	Department of Environmental Engineering Sciences, University of Florida
William Waugh	U.S. EPA, Health and Environmental Review Division

Terminology

We received numerous comments concerning some of the terminology used in the report. We have reviewed carefully all of the suggestions, and have incorporated most of them in the final report. For example, several commenters did not like the term "best estimate" when referring to the estimates of nationwide cancer incidence obtained as the result of the reduction analyses. In the final report, we now use the term "point estimate," even though for four pollutants our "point" estimate of nationwide annual cancer incidence is still a range (rather than a single number).

Several commenters requested that we use the term "upper-bound" to qualify our nationwide estimates. We have not done this in the final report. We believe that to describe the estimates as upper-bound would not be an appropriate descriptor of national estimates aggregated across a limited set of pollutants and source categories studied. It is possible that the risk methodologies and as yet unquantified risks from other pollutants and sources may make the use of "upper-bound" inappropriate. We agree that the unit risk factors in and of themselves are upper-bound estimates. However, other factors that enter into estimating nationwide cancer incidence may make the use of the term "upper-bound" misleading, especially since it is so closely associated with unit risk factors.

Several commenters requested that the terminology associated with lifetime individual risk be reviewed for clarity and consistency. This has been done, although some of the original detail has been retained.

In describing the risk estimates, we have revised the language to reflect past EPA descriptions that note the derivation of the unit risk factors, and that the actual risk is unknown and may even be as low as zero.

Specific Pollutants

A number of comments were received on several pollutants, mostly concerning the uncertainties associated with each one's risk. In general, the report already identified a number of uncertainties associated with individual pollutants. In addition, it is not the purpose of this report to review all of the uncertainties associated with each individual pollutant. This report rather tries to highlight some of the more important uncertainties in order to give the reader a feel for the uncertainty associated with the estimates. Other reports and studies should be reviewed for details on any individual pollutant.

Nevertheless, we have considered each point raised by the commenters. Those associated with formaldehyde have generally been incorporated, with the exception that the reported risk estimates continue to be based on the upper-bound unit risk factor and not the maximum likelihood unit risk factor. This decision is consistent with current EPA policy. The other comments generally have not been incorporated because, in our opinion, they did not add to the sense of uncertainty already presented in the report.

Source Categories

One commenter questioned the segregation of the individual source categories between point and area sources. This was reviewed, and we agree that several individual sources that were identified as area sources should have been identified as point sources. The final report makes these changes. Because of these changes, the final report shows area sources contributing approximately 75 percent of the total estimated national cancer incidence and point sources 25 percent. The draft external review draft showed a 80 percent contribution by area sources and 20 percent by point sources.

A brief discussion explaining how the source categories were divided between area and point has been added. While this should help the reader understand how we assigned the source categories, a clear distinction between area and point sources is not always possible.

Several commenters made suggestions concerning individual source categories. In most instances, these comments were not incorporated because it was felt that the text already adequately covered the comment or that the additional detail was not appropriate for this report. One commenter noted a discrepancy in the estimated cancer incidence for POTWs. This discrepancy has been corrected in the final report.

One commenter requested that the cancer risk estimates for TSDFs and sewage sludge incinerators be eliminated from the report because of the methodologies are flawed and the estimates from them are not meaningful. We have retained the estimates from these two source categories. We agree that these two source categories have uncertain risk estimates, and this has been noted in the appropriate spots in the report.

ATERIS/SARA Title III

Several comments were received concerning the ATERIS data base and the use of toxic emission information received under SARA Title III. The SARA Title III data are not reported in a form that allows for the development of risk estimates. It is outside the scope of this study to develop original analyses based on those data. Thus, the SARA Title III data are not used in this report. Future updates of this report will include the results of any risk analyses based on the SARA Title III data. In the meantime, the risk estimates from the ATERIS data base have been retained in the final report. These estimates are available, and we believe do provide useful information. In addition, they have been adequately caveated in an attempt to limit their misuse.

Uncertainty in Cancer Risk Estimates

Several commenters requested that we segregate the cancer incidence estimates for the individual pollutants on the basis of the relative uncertainty with each estimate. We agree that this can be a desirable segregation. However, such an effort is outside the scope of resources allocated to this study. Further, we believe that there is sufficient information in the report that allows the reader to gain a sense of the relative uncertainty of each of the estimates. Thus, the final report does not incorporate this suggestion.

Perspective of Cancer Estimates to Total Cancer

Several commenters suggested that a brief paragraph relating the estimates of cancer risk from outdoor exposure to air toxics to estimates of total cancer incidence. We agree that such a comparison is useful for the reader, and have addressed this comment in the Executive Summary.

Maximum Exposed Individual

One commenter suggested that the method for calculating the risk to the maximum exposed individual should be redone by collecting some actual data of residential living patterns and human activity patterns. According to the commenter, it is not defensible at this stage to continue to use totally unrealistic assumptions, especially since these MEI/MIR numbers may take on increasing regulatory importance in the future. This comment could not be responded to within the context of this report. Therefore, the methodology used to estimate the MEI/MIR estimates has not been changed.

APPENDIX B

CANCER RISK REDUCTION ANALYSIS FOR SELECTED POLLUTANTS

The purpose of this appendix is to present the reduction analyses for the 23 individual pollutants that were initially identified as possibly resulting in at least 10 cancer cases per year nationwide. The analyses derive a point estimate, or as narrow a range as possible, of the annual cancer cases per million population for each pollutant/source category combination from the range of estimates found in the various reports and studies. The specific data on the estimated number of annual cancer cases and the estimated annual cancer cases per million population for a pollutant by each source category for each study are presented in this appendix. The annual cancer cases per million population are shown in parentheses in the tables. NOTE: Unless otherwise noted, all risk estimates have been adjusted based on a consistent set of unit risk factors.

Please note that the last two columns in each table are "Range" and "Point Estimate". The numbers in these two columns are estimates of nationwide annual cancer cases. The estimates are conservative in that actual risk may be higher, but is more likely to be lower.[1] For the "Range" column, the estimates of nationwide annual cancer cases were calculated, in most instances, by taking the lowest and highest annual cancer cases per million population for a source category and multiplying it by 240 (1986 U.S. population in millions). The "Total" for this column simply represents the summation of the low end of the range and the summation of the high end of the range. The column labeled "Point Estimate" presents the estimates of nationwide annual cancer incidence based on the results of the reduction analyses. The text discusses how the ranges and point estimates were selected.

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[1] The unit risk factors used to estimate cancer risk are based on a linearized multistage procedure that leads to a plausible upper limit to the risk that is consistent with some proposed mechanisms of carcinogenesis. Such an estimate, however, does not necessarily give a realistic prediction of the risk. The true value of the risk is unknown, and may be as low as zero.

Where the cancer incidence for a pollutant was estimated with both modeled concentrations and ambient-measured concentrations, this is shown in the "Totals" row. Separate headings are given for the modeled concentration-based estimates (i.e., "Modeled") and for the ambient-measured concentration-based estimates (i.e., "Ambient"). Some studies estimated cancer incidence using both types of concentrations. For these studies, entries are made for both "Modeled" and "Ambient" totals.

An index to the pollutants covered in this appendix is presented below.

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Vinylidene chloride	B-135

Acrylonitrile. Point sources of acrylonitrile include acrylonitrile monomer production, acrylic and modacrylic fiber production, ABS/SAN resin production, nitrile rubber production, and acrylamide and adiponitrile production. Other production processes that consume a small percentage of acrylonitrile are nitrile barrier resin production, fatty amine production, and as an absorbent.[2] Acrylonitrile emissions have also been identified as occurring from publicly owned treatment works (POTWs) and treatment, storage, and disposal facilities (TSDFs).

Seven studies included acrylonitrile as a pollutant of concern (see Table B-1). Seven specific source categories were examined. Three of the studies (35-County, the IEMP-Kanawha Valley, and the Southeast Chicago studies) did not identify the specific types of plants included. A comparison of plant locations in the NESHAP/ATERIS data base with the counties included in the 35-County study revealed that some of the counties examined in the 35-County study had acrylonitrile sources covered in the NESHAP/ATERIS data base. On the other hand, none of the plant locations examined in the NESHAP/ATERIS data base were identified as being in the areas covered by the IEMP-Kanawha Valley study.

The annual incidences were based on modeled estimates of ambient concentrations. The IEMP-Kanawha Valley used a box model and an ISCLT model. The box model was known to likely overestimate actual exposure levels, but was used in the study to bound the problem. For the TSDF study, the annual incidence attributable to acrylonitrile was estimated by assuming the annual incidence from acrylonitrile was proportional to

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[2] U.S. EPA. Locating and Estimating Air Emissions from Sources of Acrylonitrile. EPA 450/4-84-007a. March 1984.

TABLE B-1

ESTIMATED ANNUAL CANCER CASES FROM ACRYLONITRILE BY SOURCE CATEGORY

SOURCE CATEGORY	INDIVIDUAL STUDY							NATIONWIDE	
	NESHAP/ ATERIS	POTWs	TSDFs	Sewage Sludge Incinerators	Thirty-five County	IEMP-Kanawha Valley	Southeast Chicago	RANGE[a]	POINT ESTIMATE[b]
POTW's		0.4 (0.002)			0.09 (0.002)			0.4	0.4
TSDF's			11 (0.046)				x	11	11
Sewage Sludge Incinerators				0.98 (0.004)				0.98	0.98
Monomer	0.054 (0.00023)							0.05	0.05
ABS/SAN	0.13 (0.00054)							0.13	0.13
Acrylic Fibers	0.073 (0.00029)							0.07	0.07
Nitrile Elastomers	0.16 (0.00067)							0.16	0.16
Chemical Mfg.						0.08-0.19 (0.8-1.9)		0.08-0.19	0.08[c]
Point Sources					0.25 (0.005)		x	0-1.3	0
TOTALS MODELED	0.42 (0.0018)	0.4 (0.002)	11 (0.046)	0.98 (0.004)	0.34 (0.007)	0.08-0.19 (0.8-1.9)	<0.0001 <(0.00002)	12.9-14.3	12.9

Footnotes to Table B-1.

NOTE: Numbers in parentheses are annual cancer cases per million population. For nationwide studies, annual cancer cases were divided by 240 million, unless otherwise noted. For studies with smaller geographic scopes, the annual cancer cases were divided by the study's population.

NOTE: An "x" in a column indicates that the source category was considered in the study, but a specific cancer risk for the source category was not indicated.

[a] The numbers in this column were calculated by taking the lowest and highest incidence rates for a source category and multiplying it by 240 (1986 U.S. population in millions). The total for this column is the summation of the low end of the range and the sum of the high end of the range.

[b] The numbers in this column present the results of the reduction analysis. In most instances, a point estimate of nationwide annual cancer incidence was derived for each pollutant/source category combination. In some instances, a point estimate could not be reasonably derived. For these instances, as narrow a range as possible of nationwide annual cancer incidence was estimated, and such ranges appear in this column. The text discusses how these point estimates and ranges were derived.

[c] Does not include extrapolating the incidence rates from the IEMP-Kanawha Valley study to nationwide cancer risk estimate because of the uncertainty as to the type of facility being modeled.

its relative contribution to the weighted unit risk factor used to estimate the total annual incidence from TSDFs. This is a very crude estimate.

Point Estimate. Excluding for the moment the estimated annual cancer cases from the chemical manufacturing source category of the IEMP-Kanawha Valley study and from TSDFs, the estimated annual cancer cases from the other five studies total between 2 and 3 cancer cases per year. It is quite likely that there is some double counting between the NESHAP/ATERIS estimates and the 35-County estimate for point sources (because, as noted above, some of the acrylonitrile sources identified in the NESHAP/ATERIS data base are located in counties evaluated in the 35-County study). Double counting is also likely with regard to the POTW estimates in the 35-County study and the POTW study. With regard to the chemical manufacturing sources in the IEMP-Kanawha Valley study, it does not appear that these sources are included in the NESHAP/ATERIS data base. Since the sources of acrylonitrile emissions in the IEMP-Kanawha Valley study are point source emissions related to a specific-type, but unknown, chemical manufacturing facility, it is not possible to estimate annual cancer cases beyond this study's limited geographic range, and it would be unreasonable to apply its annual cancer incidence per million population to the entire U.S. population to obtain a national estimate. Taking these things into consideration, the point estimate of total annual cancer cases from these five studies is estimated to be approximately two cancer cases per year.

As noted earlier, the estimated cancer cases from TSDFs is a very crude estimate, but is the only estimate available at this time. Since the TSDF study is a national estimate, it most likely includes the Southeast Chicago study area. Even if it does not, the negligible estimated cancer cases from TSDFs in the Southeast Chicago study would not affect the estimate of annual cancer cases from TSDFs (i.e., 11 cancer cases per year). Combining the six studies, a total of 13 cancer cases per year nationwide from exposure to acrylonitrile emissions is estimated.

Arsenic. Arsenic is emitted from a number of point and area sources. Point sources include smelters, glass manufacturing, and steel mills. Area sources are primarily combustion related activities.

Thirteen studies included arsenic as a pollutant of concern (see Table B-2). Of these studies, three estimated annual cancer cases on the basis of ambient measurements (the IEMP-Santa Clara study, the South Coast study, and the Ambient Air Quality study) and the other ten used modeling to estimate ambient concentrations and cancer cases. The South Coast study also included an estimate based on modeling.

Ambient Estimates. The South Coast study estimated 1.5 cancer cases per year, or approximately 0.14 cases per year per million population, based on an average ambient concentration of approximately 2.4×10^{-3} micrograms per cubic meter ($\mu g/m^3$). This estimate was based on over 300 individual samples at a total of 7 sampling sites; 24 of the samples were below the minimum detectable limits. The IEMP-Santa Clara study estimated 0.2 to 0.4 annual cancer cases, or approximately 0.14 to 0.29 cancer cases per year per million population. The lower estimate reflects half of the minimum detectable limit of the analytical equipment used (i.e., one-half of 0.0055 $\mu g/m^3$). The upper estimate reflects the average of the lower estimate with the samples above the minimum detectable limits. The Ambient Air Quality study estimate of 68 annual cancer cases, or approximately 0.28 cancer cases per year per million population, was based on 163 areas with ambient data. Because of the larger geographic scope of the Ambient Air Quality study, 68 annual incidences was selected as the best estimate of cancer cases from arsenic based on ambient air quality data.

TABLE B-2

ESTIMATED ANNUAL CANCER CASES FROM ARSENIC BY SOURCE CATEGORY

SOURCE CATEGORY	INDIVIDUAL STUDY							
	Ambient Air Quality	NESHAP/ ATERIS	Coal and Oil Combustion	Hazardous Waste Combustors	Municipal Waste Combustors	Sewage Sludge Incinerators	Waste Oil Combustion	Thirty-five County
Chemical Manufacturing		0.0043 (0.00002)						
Glass Manufacturing		0.4 (0.0017)						
Non-ferrous Smelters		1.1 (0.0046)						
Coal and Oil Combustion/ Heating			5.3 (0.022)					7.46 (0.16)
Hazardous Waste Combustors				0.005 (0.00002)				
Municipal Waste Combustors					0.16 (0.0007)			x
Sewage Sludge Incinerators						0.17 (0.0007)		
Waste Oil Combustion							0.087-0.48 (0.00036-0.002)	0.64 (0.014)
Other								33.9 (0.72)
Solvent Use								
Woodsmoke								x
Steel Mills/ Iron and Steel								x
Zinc Oxide		0.08 (0.00033)						
TOTALS								
MODELED		1.6 (0.0067)	5.3 (0.022)	0.005 (0.00002)	0.16 (0.0007)	0.17 (0.0007)	0.087-0.48 (0.00036-0.002)	42 (0.89)
AMBIENT	68 (0.28)							

TABLE B-2 -- concluded

ESTIMATED ANNUAL CANCER CASES FROM ARSENIC BY SOURCE CATEGORY

SOURCE CATEGORY	INDIVIDUAL STUDY					NATIONWIDE	
	Five City	IEMP-Kanawha Valley	IEMP-Santa Clara	Southeast Chicago	South Coast	RANGE[a]	POINT ESTIMATE[b]
Chemical Manufacturing						0.0043	0.0043
Glass Manufacturing						0.4	0.4
Non-ferrous Smelters	0.01 (0.0006)					0.1-1.1	0.1-1.1
Coal and Oil Combustion/ Heating	0.37 (0.023)	0.018 (0.18)				5.3-43	5.3
Hazardous Waste Combustors						0.005	0.005
Municipal Waste Combustors						0.16	0.16
Sewage Sludge Incinerators						0.17	0.17
Waste Oil Combustion		0.0004 (0.004)				0.09-3.4	0.5
Other	0.76 (0.048)			0.0014 (0.004)		1-173	1-34
Solvent Use	0.0009 (0.000057)					0.01	0.01
Woodsmoke	0.013 (0.0008)					0.2	0.2
Steel Mills/ Iron and Steel	0			0.02 (0.05)		c	c
Zinc Oxide						0.08	0.08
TOTALS							
MODELED	1.14 (0.072)	0.018 (0.18)		0.021 (0.055)	-- --	7.5-222	8-42
AMBIENT			0.2-0.4 (0.14-0.29)		1.5 (0.143)	34-70	68

Footnotes to Table B-2.

NOTE: Numbers in parentheses are annual cancer cases per million population. For nationwide studies, annual cancer cases were divided by 240 million, unless otherwise noted. For studies with smaller geographic scopes, the annual cancer cases were divided by the study's population.

NOTE: An "x" in a column indicates that the source category was considered in the study, but a specific cancer risk for the source category was not indicated.

[a] The numbers in this column were calculated by taking the lowest and highest incidence rates for a source category and multiplying it by 240 (1986 U.S. population in millions). The total for this column is the summation of the low end of the range and the sum of the high end of the range.

[b] The numbers in this column present the results of the reduction analyses. In most instances, a point estimate of nationwide annual cancer incidence was derived for each pollutant/source category combination. In some instances, a point estimate could not be reasonably derived. For these instances, as narrow a range as possible of nationwide annual cancer incidence was estimated, and such ranges appear in this column. The text discusses how these point estimates and ranges were derived.

[c] Estimate for this source category was assumed to be included in the "other" source category. See text for explanation.

Modeled Estimates. The estimates of cancer cases based on modeling provide for a wider range of estimates. One difficulty in assembling Table B-2 was ensuring that the categories are mutually exclusive. The most important examples in terms of estimated cancer cases are the categories "Heating" and "Other/Point Sources." The "heating" category, which was used in the IEMP-Kanawha Valley study and the 35-County study, was assumed to be the same as or a subcategory to the "Coal and Oil Combustion" category of the Coal and Oil Combustion study,[3] as were the "utility boilers" and "oil combustion" categories of the 5-City study.

There are four source categories in Table B-2 for which more than one study estimated cancer cases. For "coal and oil combustion/heating," the IEMP-Kanawha Valley and the 35-County studies, which used "heating" to describe the source category, both estimated nearly identical cancer cases per year per million population rates (0.18 versus 0.16, respectively). These estimates are higher than the coal and oil combustion estimates in the Coal and Oil Combustion and the 5-City studies, both of which calculated approximately 0.022 cancer cases per year per million population. One reason for this difference in annual cancer incidences per million population appears to be the use of different emission factors. (Both sets of annual cancer incidences per million population already have been "corrected" for unit risk factors.) The 5-City study notes that the coal and oil combustion emission factors for arsenic, chromium, formaldehyde, and nickel were revised from those of the original 5-City study using more recent test data, whereas the 35-County study notes that newer source factors for area sources such as heating and waste oil burning were not included within the updated 35-County study. Thus, it appears that a best estimate of nationwide risk from this source category would be based on the annual cancer incidences per million population from the Coal and Oil Combustion and 5-City studies, which yield an estimated 5 cancer cases per year.

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[3] The 35-County study identified heating as being composed of commercial, industrial, and residential heating by fuel type, i.e., coal and oil. This is the same type of breakdown as in the Coal and Oil Combustion study.

Three studies included "Waste oil combustion" as a source category. Although a fairly wide range of cancer cases per year per million population is shown (0.0004 to 0.014), total annual cancer cases are relatively small (less than 4 per year at the highest annual cancer incidence per million population). The higher estimate is from the 35-County study, and as noted above, the 35-County study apparently did not incorporate newer source factors for waste oil burning. Although emission factors between the studies could not be compared, as a specific national study on waste oil burning was available, the estimate from that study (0.5 annual cancer cases) was selected as the best estimate.

Two studies included "non-ferrous smelters" sources - the NESHAP/ATERIS data base and the 5-City study. Because of the specific locations of the non-ferrous facilities and the national scope of the study, the NESHAP/ATERIS data base estimate was selected as the best estimate.

Three studies include a source category for "other" sources. For the 35-County study, the cancer risk associated with this source category is large, 34 cancer cases per year, or approximately 0.72 cancer cases per year per million population. It is unclear as to what sources were modeled to obtain this estimate, although municipal incinerators and steel mills (coke ovens) were included. For the 5-City study, the "other" source category shows a cancer rate of approximately 0.05 cancer cases per year per million population. Again, the sources included in this category are unspecified, although it is clear that "iron and steel" is not included. The 5-City study did not report any annual cancer risk due to arsenic emissions from iron and steel mills. Finally, the Southeast Chicago study showed a relatively small annual cancer incidence per million population for the "other" category (0.004 cancer cases per year per million population), but a more significant one for steel mills (0.05 cancer cases per year per million population). For the "other" and "iron and steel/steel mills" source categories, a combined range of 0.05 to 0.72 cancer cases per year per million population can be created. Based on the 35-County and the Southeast Chicago studies, steel mills appear to be the largest contributor to this annual cancer incidence per million population. To apply the annual cancer incidences per million population from these two studies for these two source categories to the total U.S. population would result in an estimated 13 to 173 cancer cases per year. One difficulty with this is that steel mills are site-specific sources that cannot easily be extrapolated to national estimates. For example, the Southeast Chicago study modeled four steel mills and the 35-County study selected counties that, in part, were known to have sources emitting the pollutants being studied, in this case arsenic. Thus, it is unlikely that applying the annual cancer incidences per million population from these two studies to the entire U.S. population is appropriate.

Because of the uncertainty associated with the sources included in the "other" source categories and with extrapolating risk from the "steel mills/iron steel" source category, it is extremely difficult to narrow the range of risks. Excluding these two source categories, a total of approximately 8 cancer cases per year nationwide is estimated. If the cancer risk from the 35-County study is primarily attributable to steel mills/iron and steel, then the nationwide estimate could be increased to 42 (8 plus 34), keeping in mind that not all steel mills may be located in these 35 counties.

Point Estimate. The best estimate of nationwide cancer cases using ambient measured data appears to be 68 cancer cases per year. For modeled estimates, a range of 8 to 222 annual cancer cases was developed. For reasons noted above, the upper end is a likely overestimation. Because of the uncertainties in trying to narrow the modeling range (which was narrowed to 8 to 42 annual cancer cases) and the relative extensiveness of the ambient data, the Ambient Air Quality study's estimate of 68 annual cancer cases was preferred. Thus, a total of 68 cancer cases nationwide due to exposure to arsenic is estimated.

Asbestos. Annual cancer cases as a result of asbestos emissions have been estimated for point sources, such as fabrication, milling, renovation, and demolition, and from motor vehicles (see Table B-3). One study examined point sources and three studies examined motor vehicles. All four studies used models to estimate cancer risk. Annual cancer cases due to asbestos emissions from point sources were estimated to be approximately 82 per year under current compliance conditions with the current asbestos standards. If full compliance with current regulations were being met, annual cancer cases from point sources would be less than 1 per year.

Using a range of unit risk factors derived from the National Academy of Sciences (NAS), the Mobile Source study estimated urban cancer cases due to asbestos from motor vehicles to be 0.41 cases per year based on an emission rate of 4 μg/mile and 113.4 cases per year based on an emission rate of 27 μg/mile. The emission rate factors of 4 μg/mile and 28 μg/mile were estimated to result in maximum annual average asbestos levels in a central city area of approximately 2.5×10^{-4} $\mu g/m^3$ and 1.75×10^{-3} $\mu g/m^3$, respectively. Adjusting the estimated annual incidences to a unit risk factor of 7.6×10^{-3} $(\mu g/m^3)^{-1}$ (as listed in Table 2-6) results in a narrower range of estimated incidence -- 4.7 to 33 cancer cases per year. According to the report, the 4 μg/mile emission rate may be a better overall estimate than the 28 μg/mile. Using 4 μg/mile, the 4.7 cancer cases per year translates into approximately 0.026 cases per year per urban million population (urban population equal 180 million).

The 5-City study shows cancer rates for motor vehicles ranging from 0.0013 to 0.012 cancer cases per year per million population, with a five-city average of 0.008 per million population. Without knowing

TABLE B-3

ESTIMATED ANNUAL CANCER CASES FROM ASBESTOS BY SOURCE CATEGORY

	INDIVIDUAL STUDY				NATIONWIDE	
SOURCE CATEGORY	Asbestos	Mobile Sources	Five City	Southeast Chicago	RANGE[a]	POINT ESTIMATE[b]
Milling	0.004-0.005 (<0.00021)				0.004-0.005	0.005
Manufacturing	0.3-0.7 (0.0013-0.003)				0.3-0.7	0.5
Fabricating	0.05-0.2 (0.0002-0.0008)				0.05-0.2	0.13
Renovation	0.41 (0.0017)			0.00057[c] (0.0015)	0.41	0.41
Demolition	80.5 (0.335)				80.5	80.5
Motor Vehicles		4.7-33[d] (0.026-0.183)	0.13 (0.008)	0.0014 (0.004)	1-44	6.24[e]
TOTALS						
MODELED	81.2-81.8 (0.34)	4.7-33 (0.026-0.183)	0.13 (0.008)	0.002 (0.005)	82-126	87.8

NOTE: Numbers in parentheses are annual cancer cases per million population. For nationwide studies, annual cancer cases were divided by 240 million, unless otherwise noted. For studies with smaller geographic scopes, the annual cancer cases were divided by the study's population.

[a] The numbers in this column were calculated by taking the lowest and highest incidence rates for a source category and multiplying it by 240 (1986 U.S. population in millions). The total for this column is the summation of the low end of the range and the sum of the high end of the range.

[b] The numbers in this column present the results of the reduction analyses. In most instances, a point estimate of nationwide annual cancer incidence was derived for each pollutant/source category combination. In some instances, a point estimate could not be reasonably derived. For these instances, as narrow a range as possible of nationwide annual cancer incidence was estimated, and such ranges appear in this column. The text discusses how these point estimates and ranges were derived.

[c] Includes "demolition." Based on data contained in the background information document to support the Asbestos NESHAP. Scaled national estimates of asbestos emissions based on number of households.

[d] Risk estimates adjusted from original study by using a unit risk factor of 2.3×10^{-1} $(\text{fibers/ml})^{-1}$. Estimate is for urban population only (180×10^6 population). Original risk estimates were 0.41 to 113.4 cancer cases per year, which reflect the use of an NAS-derived range of unit risks.

[e] Reflects applying the urban incidence rate from motor vehicles of 0.026 annual cancer cases per urban million population to total U.S. population.

the emission factors used in the 5-City Study, it is difficult to determine the differences in the annual cancer incidences per million population estimated for these two studies.

The Southeast Chicago study used an asbestos emission factor of 4 μg/mile and a unit risk factor of 8.1×10^{-3} $(\mu g/m^3)^{-1}$ to estimate cancer incidence from mobile sources. The Southeast Chicago study estimated approximately 0.0014 cancer cases per year, or 0.004 cancer cases per year per million population. This annual cancer incidence per million population falls within the range created in the 5-City study for the five individual cities, but is approximately 6.5 times smaller than the annual cancer incidence per million population from the Mobile Source study based upon the same emission factor of 4 μg/mile. Different models were used in estimating risk between the two studies, and this difference may explain the different annual cancer incidences per million population. However, the information available is insufficient to resolve this difference.

Point Estimate. For point sources, the best nationwide estimate is 82 cancer cases per year. For motor vehicles, a range between 1 and 44 annual cancer cases can be created. The lower estimate applies the Southeast Chicago study's annual cancer incidence per million population to the total U.S. population and the upper estimate applies the upper annual cancer incidence per million population from the Mobile Source study to total U.S. population. Since the differences between the Mobile Source study and the 5-City and the Southeast Chicago studies cannot be resolved at this time, the results of the Mobile Source study were selected as the best estimate for calculating nationwide incidence. As the 4 μg/mile emission rate appears to be a better overall estimate than 28 μg/mile, the upper end of the range may be closer to 6 cancer cases per year (0.026 cancer cases per year per urban million times 240 million) than to 44 cancer cases per year. Although this applies urban data to rural populations, the difference in total annual incidence is small (5 vs. 6 cancer cases per year). In light of these considerations, the best estimate of cancer risk from motor vehicles is selected as approximately 6 cancer cases per year. Combining the estimates, a total of 88 cancer cases per year nationwide from exposure to asbestos is estimated.

Benzene. Benzene emissions occur from a multitude of sources, both point and area sources. Most of the emissions are associated with gasoline and other fuel combustion (such as motor vehicles) and marketing (such as service stations). Fifteen studies included benzene as a pollutant of concern, covering approximately 20 source categories (see Table B-4).

Several of the studies estimated cancer risk using ambient measurements or compared ambient measurements with modeled ambient concentrations. In studies that compared ambient measurements with modeled ambient concentrations (e.g.,the South Coast study, the Southeast Chicago study, and the IEMP-Philadelphia study), ambient measured concentrations were generally about two times higher than the modeled concentrations. This is considered to be a fairly reasonable agreement.

Ambient Estimates. The Ambient Air Quality study was the only study to rely solely on ambient measurements to estimate the risk from benzene. Ambient concentrations ranged from approximately 3 $\mu g/m^3$ to 15.5 $\mu g/m^3$ for individual city (urban) averages. The national urban population weighted average concentration was 8.07 $\mu g/m^3$ and the national rural population average concentration was 0.6 $\mu g/m^3$. Based on these average concentrations, annual cancer incidences were estimated to be 181 per year, with a cancer rate of 0.75 cancer cases per year per million population.

The other studies that included ambient measured concentrations included the South Coast study, the Mobile Source study, the Southeast Chicago study, the IEMP-Baltimore study, and the IEMP-Philadelphia

TABLE B-4

ESTIMATED ANNUAL CANCER CASES FROM BENZENE BY SOURCE CATEGORY

SOURCE CATEGORY	INDIVIDUAL STUDY									
	Ambient Air Quality	NESHAP/ ATERIS	Gasoline Marketing	Mobile Sources	TSDFs	Waste Oil Combustors	Thirty-five County	Five City	IEMP-Baltimore	IEMP-Kanawha Valley
Gasoline Marketing		3.45 (0.014)	6.8 (0.028)				0.47 (0.01)	0.267 (0.017)		0.00094 (0.0094)
Bulk Terminals		0.07 (0.0003)								
Chemical Mfg.		0.073 (0.0003)						0.208 (0.013)		
Benzene Fugitives		0.2 (0.0008)								
Benzene Storage		0.05-0.1 (0.0002-0.0004)								
EBS		0.004 (0.00002)								
Waste Oil Burning						0.00017 (0.00000071)	negligible			
Motor Vehicles				95-101 (0.4-0.42)			15.1 (0.32)	6.23 (0.392)		0.039 (0.39)
Iron and Steel		3 (0.013)					x	0.34 (0.021)		
Refinery								0.076 (0.0048)		
Other Organic Evaporation								0.26 (0.016)		
Sewage Sludge Incinerators										

TABLE B-4 -- continued

ESTIMATED ANNUAL CANCER CASES FROM BENZENE BY SOURCE CATEGORY

SOURCE CATEGORY	INDIVIDUAL STUDY									
	Ambient Air Quality	NESHAP/ ATERIS	Gasoline Marketing	Mobile Sources	TSDFs	Waste Oil Combustors	Thirty-five County	Five City	IEMP-Baltimore	IEMP-Kanawha Valley
Woodsmoke								0.874 (0.055)		
Heating							0.1 (0.002)	0.0067 (0.0004)		
POTWs							0.07 (0.0015)			
Burning Waste Material										
Industrial Solvent Coatings										
Pesticide Usage										
Unspecified Stationary							6.2 (0.13)			
TSDFs					0.44 (0.0018)					
Area Sources										
TOTALS										
MODELED		6.92 (0.029)	6.8 (0.028)	95-101 (0.4-0.42)	0.44 (0.0018)	0.00017 (0.00000071)	21.9 (0.46)	8.26 (0.52)		0.043 (0.43)
AMBIENT	181 (0.75)			155 (0.65)					1.9 (1.2)	

TABLE B-4 -- continued

ESTIMATED ANNUAL CANCER CASES FROM BENZENE BY SOURCE CATEGORY

SOURCE CATEGORY	INDIVIDUAL STUDY					NATIONWIDE	
	IEMP-Philadelphia	IEMP-Santa Clara	Southeast Chicago	South Coast	Sewage Sludge Incinerators	RANGE[a]	POINT ESTIMATE[b]
Gasoline Marketing	0.0032 (0.0019)	0.009 (0.0067)				1.6-6.8	6.8
Bulk Terminals						(see gas marketing above)	
Chemical Mfg.		0.0029 (0.002)				0.07-3.1	0.07
Benzene Fugitives						0.2	0.2
Benzene Storage						0.1	0.1
EBS						0.004	0.004
Waste Oil Burning						negligible	negligible
Motor Vehicles		0.172 (0.12)	0.027 (0.069)	4.7 (0.43)		17-103	98
Iron and Steel			0.031 (0.08)			3-19	5
Refinery	0.0099 (0.006)					1-1.4	1
Other Organic Evaporation		0.007 (0.0048)				1-4	4
Sewage Sludge Incinerators					0.09 (0.0004)	0.09	0.09

TABLE B-4 -- concluded

ESTIMATED ANNUAL CANCER CASES FROM BENZENE BY SOURCE CATEGORY

SOURCE CATEGORY	INDIVIDUAL STUDY					NATIONWIDE	
	IEMP-Philadelphia	IEMP-Santa Clara	Southeast Chicago	South Coast	Sewage Sludge Incinerators	RANGE[a]	POINT ESTIMATE[b]
Woodsmoke						13	13
Heating		0.025 (0.018)				0.01-4	0.5
POTWs	0.00035 (0.0002)		negligible			0.05-0.4	0.4
Burning Waste Material		0.0007 (0.0005)				0.1	0.1
Industrial Solvent Coatings		0.056 (0.04)				10	10
Pesticide Usage		0.0164 (0.012)				3	3
Unspecified Stationary		0.01 (0.007)	0.00086 (0.0022)	3.8 (0.35)		c	c
TSDFs			negligible			0.44	0.44
Area Sources			0.0014 (0.0036)			0.86	0.86
TOTALS							
MODELED	0.0135 (0.008)	0.3 (0.22)	0.061 (0.155)	8.6 (0.79)	0.09 (0.0004)	52-171	143
AMBIENT	1.2 (0.71)	1.25 (0.89)		15.5 (1.42)		181-341[d]	181

Footnotes to Table B-4.

NOTE: Numbers in parentheses are annual cancer cases per million population. For nationwide studies, annual cancer cases were divided by 240 million, unless otherwise noted. For studies with smaller geographic scopes, the annual cancer cases were divided by the study's population.

NOTE: An "x" in a column indicates that the source category was considered in the study, but a specific cancer risk for the source category was no indicated.

[a] The numbers in this column were calculated by taking the lowest and highest incidence rates for a source category and multiplying it by 240 (198 U.S. population in millions). The total for this column is the summation of the low end of the range and the sum of the high end of the range.

[b] The numbers in this column present the results of the reduction analyses. In most instances, a point estimate of nationwide annual cancer incidence was derived for each pollutant/source category combination. In some instances, a point estimate could not be reasonably derived. For these instances, as narrow a range as possible of nationwide annual cancer incidence was estimated, and such ranges appear in this column. The text discusses how these point estimates and ranges were derived.

[c] A range is not shown because the two highest incidence rates (from the 35-County study and the South Coast study) were considered to be duplicative of the other source categories as well as, in the case of the South Coast study, non-representative for extrapolation to a nationwide estimate.

[d] Range does not include mobile sources as that range estimate was derived from the Ambient Air Quality study's concentrations.

study. Except for the Mobile Source study, all of the ambient concentrations reported in the other studies were within the range of concentrations for urban areas in the Ambient Air Quality study. For example, the concentrations in the South Coast study were between 7.9 and 15.4 $\mu g/m^3$; in the Southeast Chicago study, between 3.6 and 5.1 $\mu g/m^3$; and in the IEMP-Philadelphia study, 6 $\mu g/m^3$. The ambient data in the IEMP-Baltimore study was considered marginal in that study. The Mobile Source study used "old" national average ambient measured concentration to estimate the mobile source contribution to benzene risk. This method has been updated to reflect the "new" national average ambient concentrations in the Ambient Air Quality study.

For the national estimate for cancer risk from ambient measured concentrations of benzene, the annual cancer incidence estimated in the Ambient Air Quality study would represent the best estimate. The other studies illustrate the geographic variation that can occur and by themselves are not the best estimates from which to extrapolate nationwide risk from benzene.

Modeled Estimates. Except for the Ambient Air Quality study and the IEMP-Baltimore study, all of the studies estimated cancer risk from modeled ambient concentrations of benzene. Approximately twenty source categories were identified as benzene emission sources. About one-half of the source categories were overlapping between the studies. Of these, only the motor vehicle and the iron and steel source categories appear to potentially contribute more than 10 cancer cases per year. Of the other source categories, industrial solvent coatings in the IEMP-Santa Clara study and the unspecified stationary source category in the 35-County and the South Coast studies have annual cancer incidences per million population that would result in about 10 or more annual cancer cases nationwide if applied to the total U.S. population.

The cancer rate from stationary sources ranges from approximately 0.15 to 0.28 cancer cases per year per million population, excluding the 35-County's and the South Coast's unspecified stationary source category. The South Coast's unspecified stationary source annual cancer incidence per million population is between 25 and 130 percent higher, being 0.35 cancer cases per year per million population. This is consistent with the higher measured ambient concentration in the South Coast study of 12 $\mu g/m^3$, which is approximately 44 percent higher than the national urban average of 8.35 $\mu g/m^3$ found in the Ambient Air Quality study. Thus, the South Coast study's estimate is probably a very geographic-specific annual cancer incidence per million population that one can not reasonably use to extrapolate nationwide risks. The 35-County's unspecified stationary source annual cancer incidence per million population is close to the lower end of this range (0.13 vs. 0.15 cancer cases per year per million population). It is known that this source category in the 35-County study contains iron and steel sources (coke ovens), which can contribute a significant portion of this risk from benzene emissions from stationary sources. This is illustrated by the results of the Southeast Chicago study, where iron and steel sources contributed to approximately one-half (0.08) of the total annual cancer incidence per million population in that study. Lacking more specific information on the specific stationary sources, this source category in the 35-County study was considered duplicative of the stationary sources in the other studies.

Of the individual source categories with "overlapping" estimates, only the motor vehicle category will be discussed in detail. As seen in

Table B-4, seven studies estimated cancer risk from motor vehicles. Five of these seven studies have very similar cancer rates, ranging between 0.32 and 0.43 cancer cases per year per million population. The IEMP-Santa Clara study's model was identified in that study as underestimating benzene emission levels by 2 to 3 times. Increasing modeled emission levels two to three times would increase the cancer rate in the IEMP-Santa Clara study to between 0.25 and 0.38 cancer cases per year per million population. This is certainly in line with the other studies. The Southeast Chicago study also noted that its modeled estimates appeared to underestimate measured ambient concentrations by two to three times. Using the measured ambient concentrations increases the Southeast Chicago estimated cancer rate to between 0.14 to 0.21 cancer cases per year per million population. While this is below the other annual cancer incidence per million populations, it is consistent with the lower measured ambient concentrations in the Southeast Chicago study, which were between 3.6 and 5.1 $\mu g/m^3$. Thus, what we are seeing are differences in the modeling techniques as well as geographic variations.

Point Estimate. The best estimate from modeled concentrations appears to be about 143 cancer cases per year nationwide (0.6 cancer cases per year per million population) and about 181 cancer cases per year nationwide (or approximately 0.75 cancer cases per million population) from ambient measured concentrations. As noted above, two of the studies discussed how the models underestimated benzene concentrations (by a factor of 2 to 3). These underestimations could be simply due to incomplete emission inventories in those studies and the narrower underestimation (0.6 vs. 0.75) in the present study due to a more complete accounting created by examining more studies and source categories. Based on these considerations, the ambient-based estimate of 181 cancer cases per year (based on 0.75 cancer cases per year per million population) was selected as the estimate of nationwide annual cancer incidence due to exposure to benzene.

1,3-Butadiene. Eight studies examined 1,3-butadiene (see Table B-5). Emission sources of 1,3-butadiene include point sources, primarily synthetic rubber producers, and area sources (e.g., motor vehicles). One study (the 35-County study) identified motor vehicle emissions of 1,3-butadiene occurring from both exhaust and tire wear. Seven studies used modeled estimates to calculate cancer risk and one study, the Ambient Air Quality study, used ambient measurements.

Modeled Estimates. Five of the seven studies included point sources. Of these five, the NESHAP/ATERIS data base, the 5-City study, and the TSDF study identified the specific types of sources; the 35-County and the IEMP-Kanawha Valley studies did not. Thus, an effort was made to determine whether any of the sources in the NESHAP/ATERIS data base were included in the IEMP-Kanawha Valley and the 35-County studies. Based on information in the IEMP-Kanawha Valley study report, the point source facility is located in Institute, West Virginia. The NESHAP/ATERIS data base did not include a facility in Institute, WV, although one in Washington, WV, was included. Thus, it appears that the cancer risk from chemical manufacturing in the IEMP-Kanawha Valley is in addition to that from the NESHAP/ATERIS data base.

In contrast, a comparison of city locations in the NESHAP/ATERIS data base with the counties in the 35-County study showed an overlap of geographic areas. For the 35-County study, it is likely that the two risk estimates are not mutually exclusive, although to what extent there is an overlap has not been determined. When the annual cancer cases from the NESHAP/ATERIS data base is divided by the exposed population, the cancer rates from both studies are the same - approximately 0.3 cancer cases per year per million population. This strongly suggests a likelihood of much overlapping between these two studies. In the case

TABLE B-5

ESTIMATED ANNUAL CANCER CASES FROM 1,3-BUTADIENE BY SOURCE CATEGORY

SOURCE CATEGORY	INDIVIDUAL STUDY								NATIONWIDE	
	Ambient Air Quality	NESHAP/ ATERIS	Mobile Sources	TSDFs	Thirty-five County	Five City	IEMP-Kanawha Valley	Southeast Chicago	RANGE^{a}	POINT ESTIMATE^{b}
Motor Vehicles			244^{c} (1.02)		212-233^{d} (0.88-0.97)	12.1-12.3^{e} (0.76-0.84)	0.011 to 0.323^{f} (0.11-3.24)	0.10^{g} (0.25)	60-244	244
Neoprene		0.5 (0.0021)							0.50	0.50
Polybutadiene		1.2 (0.0052)							1.2	1.2
1,3-Butadiene Production		11 (0.042)							10	10
Styrene-Butadiene Rubber		10 (0.042)							10	10
Chemical Manufacturing						0.36 (0.022)	0.115 (1.15)		0.12^{h}	0.12^{h}
Point Sources					14 (0.3)				14	--
TSDFs				0.29 (0.001)					0.29	0.29
TOTALS										
MODELED		24 (0.10)	244 (1.02)	0.29 (0.001)	68.4 (1.45)	12.1-12.3 (0.76-0.84)	0.126-0.44 (1.26-4.39)	0.10 (0.25)	96-276	266
AMBIENT	244 (1.02)								244	244

Footnotes to Table B-5.

NOTE: Numbers in parentheses are annual cancer cases per million population. For nationwide studies, annual cancer cases were divided by 240 million, unless otherwise noted. For studies with smaller geographic scopes, the annual cancer cases were divided by the study's population.

[a] The numbers in this column were calculated by taking the lowest and highest incidence rates for a source category and multiplying it by 240 (1986 U.S. population in millions). The total for this column is the summation of the low end of the range and the sum of the high end of the range.

[b] The numbers in this column present the results of the reduction analyses. In most instances, a point estimate of nationwide annual cancer incidence was derived for each pollutant/source category combination. In some instances, a point estimate could not be reasonably derived. For these instances, as narrow a range as possible of nationwide annual cancer incidence was estimated, and such ranges appear in this column. The text discusses how these point estimates and ranges were derived.

[c] Urban: 211 cancer cases per year; 1.17 annual cancer cases per million urban population. Rural: 33 cancer cases per year; 0.55 annual cancer cases per million rural population.

[d] The 35-County study estimated 4.28 annual cancer cases based on a weighted average 1,3-butadiene emission factor of 0.001 g/mile. This was adjusted to reflect an emission factor of 0.0089 to 0.0098 grams per mile (g/mile). In addition, the 35-County study noted that to adjust emissions nationwide one would divide emission approximately 0.18. When these adjustments are made, 1986 annual cancer cases are estimated to be approximately 212 to 233.

[e] Adjusted to reflect a 1986 emission factor of 0.0089 to 0.0098 g/mile. Study used 1980 emission factors, and estimated 17.7 annual cancer cases (1.13 cancer cases per year per million population).

[f] Total annual cancer cases from 1,3-butadiene were identified as 0.438. Of this, 0.115 were indicated as due to point sources. The only other 1,3-butadiene source identified in the report was "road vehicles." This would indicate 0.323 annual cancer cases (0.438-0.115) due to road vehicles. However, using concentrations from another table, annual cancer cases from each of the four study areas can be calculated. This calculation results in an estimated 0.011 annual cancer cases.

[g] Southeast Chicago study used an initial emission factor of approximately 7.9×10^{-3} g/mile.

[h] The incidence rate from the IEMP-Kanawha Valley study was assumed to be only representative of the specific locale. The incidence rate from the 5-City study was assumed to be a better incidence rate from which to estimate nationwide incidences.

of the 5-City study, all of the estimated stationary source cancer cases were from two facilities in one city. These two facilities are included in the NESHAP/ATERIS data base. Thus, the cancer estimates of the 5-City study and the NESHAP/ATERIS data base are duplicative of each other.

Based on the above, point sources appear to result in between 24 and 38 cancer cases per year, depending on the overlap between the 35-County study and the NESHAP/ATERIS data base. It seems likely that a more detailed comparison would show the estimate closer to 24 annual cancer cases than to 38.

Five studies used modeled concentrations to estimate risk from motor vehicles. In order to compare the risk estimates and annual cancer incidences per million population among the studies, a consistent emission factor was applied to four of the five studies. (The IEMP-Kanawha Valley study was not included because the study did not identify the emission factor used.) The emission factor selected to put the risk estimates on a more common basis was the estimated 1986 emission factor of 0.0089 to 0.0098 grams per mile (g/mile), which was taken from the latest work by the Office of Mobile Sources.[4] The range reflects the presence and absence of an inspection/maintenance program, respectively. After adjusting to a common emission factor (0.0089 to 0.0098 g/mile), a cancer rate range of 0.25 to 1.02 cancer cases per year per million population is created. Each of the four studies used a different model to estimate risk. The modified CO NEM model used in the Mobile Source study appears to generate higher risk estimates than the model used in the 35-County study. Thus, this range appears to be the result, in part, of the particular model used.

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[4] Carey, Penny M. and Joseph Somers. Air Toxics Emissions from Motor Vehicles. Paper presented at 81st Meeting of APCA. Dallas, TX. June 19-24, 1988.

Insufficient information was available to determine why the annual cancer incidence per million population in the IEMP-Kanawha Valley could be calculated as being from 0.11 to 3.24 annual cancer cases per million population. If the higher estimate was based on the "older" speciation factor of 0.94 percent, then correcting to the new speciation factor of 0.35 percent (as recommended by the Office of Mobile Sources) reduces the upper annual cancer incidence per million population to 1.2 annual cancer cases per million population, which is in line with the other studies.[5]

Depending on the emission factor and model used, the cancer rate for 1,3 butadiene emissions from motor vehicle appears to range between 0.76 and 1.5 cancer cases per year per million population. The annual cancer incidence per million population from the Mobile Source study (1.02 cancer cases per year per million population) was selected as the best estimate for this source category. This results in an estimated 244 cancer cases per year nationwide.

Point Estimate. The Ambient Air Quality study coincidentally resulted in an annual cancer incidence per million population the same as for the Mobile Sources study - 1.02 cancer cases per year per million population. The Ambient Air Quality study was based on data from California. Of the NESHAP/ATERIS point sources, two are located in California, but not in cities that provided 1,3-butadiene ambient measurements. It is not unreasonable to expect ambient measurements to be higher in cities with point sources. Thus, it is not unreasonable in this instance that the ambient data and the modeled point source data are mutually exclusive. On this basis, cancer incidence is estimated to be 266 annual cancer cases nationwide (22 from point sources (including TSDFs) and 244 from motor vehicles/ambient measured data) due to exposure to 1,3-butadiene.

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[5] In the past, the Office of Mobile Sources, U.S. EPA, had assumed that 0.94 percent of vehicle hydrocarbon exhaust was 1,3-butadiene. This was based on limited data for light-duty catalyst-equipped vehicles in which 1,3-butadiene and butane were reported together. Assumptions had to be made about the percentage attributable to 1,3-butadiene. In addition, due to lack of data for the other vehicle classes, it was assumed that 1,3-butadiene constituted 0.94 percent of the composite fleet HC exhaust. Recently, more recent data has been obtained specifically addressing 1,3-butadiene emission levels from current motor vehicles. The analysis of these data shows that 1,3-butadiene is emitted at a lower rate than previously assumed. Expressed as a percentage of exhaust hydrocarbon, the overall average is now estimated to be 0.35 percent.

Cadmium. Fifteen studies included cadmium as a pollutant of concern, covering approximately twelve source categories (see Table B-6). Both point and area sources are included. Four studies (the Ambient Air Quality study, the South Coast study, the IEMP-Baltimore study, and the IEMP-Santa Clara study) used ambient measured concentrations to estimate risk. The Southeast Chicago study also reported ambient measured concentrations for comparison to modeled estimates. The South Coast study also estimated risk from modeled ambient concentrations.

Modeled Estimates. Most of the source categories were included in more than one study. Most of the source categories are projected to have relatively small cancer risk (<2 annual cancer cases). Those categories for which annual cancer cases may be more than two cancer cases per year are motor vehicles, heating/combustion, and iron and steel, and sewage sludge incinerators. These source categories are discussed next.

As seen in Table B-6, risk estimates for motor vehicles are shown for five studies. Annual cancer incidences per million population range from less than 0.001 to 0.04 cancer cases per year per million population. This wide range of cancer rates appears to be due to uncertainty regarding the sources of cadmium emissions. Most of the variation can be accounted for by the use of different emission factors, whether or not cars with catalytic converters emit cadmium, and whether tire wear is included. Table B-7 tries to take these items into account for four of the five studies. The annual cancer incidence per million population for the IEMP-Kanawha Valley study falls within this range. Because of the uncertainty associated with the source of cadmium emissions, a cancer rate range of 0.001 to 0.04 annual cancer

TABLE B-6

ESTIMATED ANNUAL CANCER CASES FROM CADMIUM BY SOURCE CATEGORY

SOURCE CATEGORY		INDIVIDUAL STUDY								
		Ambient Air Quality	NESHAP/ ATERIS	Coal and Oil Combustion	Hazardous Waste Combustors	Mobile Sources	Municipal Waste Combustors	Sewage Sludge Incinerators	Waste Oil Combustors	Thirty-five County
Heating/ Combustion			1.1 (0.0046)	1.1 (0.0046)						1.83 (0.039)
Iron and Steel			0.06 (0.00025)							
Municipal Waste Combustors			0.2 (0.00083)				0.82 (0.00034)			
Smelters			0.173 (0.00072)							
Waste Oil Combustion									0.064 (0.0003)	0.06 (0.0013)
Hazardous Waste Combustors					0.012-0.24 (0.00005-0.001)					
Motor Vehicles						0.18 (0.001)				0.42 (0.0088)
Unspecified Sources										2.54 (0.054)
Sewage Sludge Incinerators			0.12 (0.0005)					3.3 (0.014)		
Manufacturing Operations			0.034 (0.00014)							
Zinc Oxide Plants			0.001 (0.000004)							
Cement Plant										
TOTALS	MODELED		1.64 (0.007)	1.1 (0.0046)	0.012-0.24 (0.00005-0.001)	0.18 (0.001)	0.82 (0.00034)	3.3 (0.014)	0.064 (0.0003)	4.85 (0.10)
	AMBIENT	10 (0.042)								

TABLE B-6 -- concluded

ESTIMATED ANNUAL CANCER CASES FROM CADMIUM BY SOURCE CATEGORY

SOURCE CATEGORY	INDIVIDUAL STUDY						NATIONWIDE	
	Five City	IEMP-Baltimore	IEMP-Kanawha Valley	IEMP-Santa Clara	Southeast Chicago	South Coast	RANGE[a]	POINT ESTIMATE[b]
Heating/ Combustion	0.145 (0.009)		0.0021 (0.021)	x			1.1-9.4	1.1-2.2
Iron and Steel					0.011 (0.029)		0.06-7.0	0.06
Municipal Waste Combustors					x		0.2-0.82	0.82
Smelters							0.173	0.173
Waste Oil Combustion			0.00009 (0.0009)				0.064-0.31	0.064
Hazardous Waste Combustors							0.012-0.24	0.012
Motor Vehicles			0.0005 (0.005)	x	0.00014 (0.00036)	0.44[c] (0.04)	0.09-9.6	0.2-9.6
Unspecified Sources	0.0033 (0.0002)				0.00014 (0.00036)	x	0.05-13	--
Sewage Sludge Incinerators							0.12-3.3	3.3
Manufacturing Operations							0.034	0.034
Zinc Oxide Plants							0.001	0.001
Cement Plant							--	--
TOTALS MODELED	0.148 (0.0092)		0.0027 (0.027)		0.012 (0.03)	0.96 (0.088)	2-44	6-16
AMBIENT		0-0.04 (0-0.026)		0.04-0.1 (0.029-0.071)		0.486 (0.045)	10-11	10

Footnotes to Table B-6.

NOTE: Numbers in parentheses are annual cancer cases per million population. For nationwide studies, annual cancer cases were divided by 240 million, unless otherwise noted. For studies with smaller geographic scopes, the annual cancer cases were divided by the study's population.

NOTE: An "x" in a column indicates that the source category was considered in the study, but a specific cancer risk for the source category was not indicated.

[a] The numbers in this column were calculated by taking the lowest and highest incidence rates for a source category and multiplying it by 240 (1986 U.S. population in millions). The total for this column is the summation of the low end of the range and the sum of the high end of the range.

[b] The numbers in this column present the results of the reduction analyses. In most instances, a point estimate of nationwide annual cancer incidence was derived for each pollutant/source category combination. In some instances, a point estimate could not be reasonably derived. For these instances, as narrow a range as possible of nationwide annual cancer incidence was estimated, and such ranges appear in this column. The text discusses how these point estimates and ranges were derived.

[c] Estimated by proportioning total risk by emissions.

TABLE B-7.

ESTIMATED ANNUAL CANCER CASES FROM CADMIUM EMISSIONS FROM MOTOR VEHICLES

	STUDY			
ITEM	Mobile Study	35 County	South Coast	Southeast Chicago
Original Estimate (Annual Incidence per million population)	0.001[a]	0.009 to 0.013[b]	0.0398[c]	0.0036[d]
1.9×10^{-6} g/mile	0.001	0.004 to 0.006	0.011	0.001
Without tire wear	0.001	0.0012 to 0.0017	0.011	0.001
Assumes cars with catalytic converters have zero cadmium emissions	0.001	<(0.0012 to 0.0017)	<0.0012[e]	0.001

[a] Exhaust emissions only; 1.9×10^{-6} grams/mile emission factor; based on 1.9×10^{-5} g/mile for non-catalytic equipped cars and 0 g/mile for cars with catalytic converters.

[b] Exhaust and tire wear emissions; 9.0×10^{-6} g/mile exhaust emission factor and 4.85×10^{-6} g/mile factor for tire; no distinction as to catalytic or non-catalytic equipped cars.

[c] Exhaust emissions only; emission factor not given; emission rate assumes all cadmium in gas (0.02 mg/l) is exhausted from both catalytic and non-catalytic equipped cars. At 0.02 mg/l, an emission factor of 6.6×10^{-6} g/mile is calculated.

[d] Based on emission factor of 6.7×10^{-7} grams/mile.

[e] Assumes 12 percent of fleet is non-catalytic equipped (same assumption as in Mobile Source Study).

cases per million population is used for the best estimate. This is equivalent to 0.2 to 9.6 cancer cases per year nationwide.

Cancer risk due to heating was found to have a fairly wide range in annual cancer incidences per million population, from approximately 0.005 to almost 0.04 cancer cases per year per million population. This is equivalent to approximately 1 to 9 cancer cases per year nationwide. The 35-County study indicated that the emission estimates for cadmium were based on species apportionment factors used in the earlier 35-County study. The 5-City study indicated species apportionment factors revised since then were used. Using the 5-City and Coal and Oil Combustion studies' estimates, a narrow range of 1.1 to 2.2 annual cases per year nationwide is obtained. Insufficient information was available to determine why the IEMP-Kanawha Valley had a higher annual cancer incidence per million population. It is possible that the urban nature of the 5-City study may contribute to the higher annual cancer incidence per million population than the one from the Coal and Oil Combustion study, but the range of 1.1 to 2.2 estimated cancer cases per year nationwide is retained.

The NESHAP/ATERIS data base and the Southeast Chicago study both estimated risk from iron and steel plants. The higher annual cancer incidence per million population in the Southeast Chicago study could be attributable to two factors. First, the Southeast Chicago study area could have a concentration of iron and steel plants that results in a higher annual cancer incidence per million population, whereas the lower annual cancer incidence per million population of the NESHAP/ATERIS data base reflects the spreading of the annual cancer cases over the entire U.S. population. As noted elsewhere, the Southeast Chicago study modeled four steel mills. Second, the Southeast Chicago study's inventory was designed to estimate actual emissions assuming full utilization of existing steel production facilities. This is apparently different from the U.S. EPA's study on steel mill emissions. The Southeast Chicago study notes that the U.S. EPA's reevaluation of steel mill emissions conducted a review of the operating status of major units at each of the steel mills in the study area. The inventory as of July 1987 is based on particulate matter emissions estimates contained in the National Emissions Data System (NEDS), which reflects sometimes outdated judgments of which units are operating and which units may be considered permanently shutdown. Thus, the Southeast Chicago study's inventory would contain a higher level of estimated emissions than under the NESHAP/ATERIS data base. For this source category, the total annual cancer cases associated with the NESHAP/ATERIS data base (0.06 per year) was selected as the best estimate of nationwide cancer risk.

The NESHAP/ATERIS data base and the Sewage Sludge Incinerator study both estimated cancer risk from sewage sludge incinerators. Since the Sewage Sludge Incinerator study is a more recent estimate, the cancer risk estimated in it was selected as the best estimate of cancer risk from cadmium from sewage sludge incinerators.

Even though there are similar wide ranges of annual cancer incidences per million population for some of the other source categories, total annual cancer cases from the remaining six source categories are estimated to most likely be less than three. Combining the best modeled estimates from all of the source categories yields an estimated 7 to 15 annual cancer cases nationwide (or between 0.029 and 0.063 cancer cases per year per million population).

The above estimate does not include the "point sources" category of the 35-County study. It was not possible to identify what overlap there might be with the other specified point source categories. However, it is known that some of the iron and steel plants are located in cities in counties that are included in the 35-County study (such as Chicago in Cook County, IL). Thus, it might be reasonable to compare the total annual cancer incidence per million population of the 35-County study with the upper end of the above range (which includes the higher annual cancer incidence per million population for the heating category from the 35-County study). When this is done, there is somewhat better agreement (0.10 vs. 0.06 cancer cases per year per million population). By adjusting the motor vehicle contribution from the 35-County study as described earlier, the total annual cancer incidence per million population for the 35-County study is lowered marginally. Considering that the counties in the 35-County study were selected, in part, on the basis of sources known to emit the pollutants being studied, it is not necessarily inconsistent that the resulting annual cancer incidence per million population is higher than the aggregate total from the nationwide studies.

Ambient Estimates. As noted earlier, four studies used ambient-measured concentrations to estimate risk. The ambient-measured concentrations of cadmium for the IEMP-Baltimore study were all below the minimum detectable limits of the analytical technique. Thus, the range of cancer cases reflects zero to the detection limit (between 0.001 and 0.002 $\mu g/m^3$) concentrations. The IEMP-Santa Clara used the 1985 Ambient Air Quality Study's concentrations (0.001 to 0.003 $\mu g/m^3$) to estimate cancer cases.

The updated Ambient Air Quality study used an annual average concentration of approximately 0.0016 $\mu g/m^3$ to estimate cancer cases. This estimate was based on data from 164 counties. The South Coast study report showed a concentration range of 0.0014 to 0.0018 $\mu g/m^3$. Both studies result in approximately the same annual cancer incidence per million population - 0.042 to 0.045 cancer cases per year per million population.

Point Estimate. The annual cancer incidences estimated from ambient-measured concentrations lie within the range derived from the modeled concentrations - 10-11 vs. 2-44 cancer cases per year. The best estimate of total nationwide cancer cases based on modeled concentration is estimated to between 6 and 16 per year. A single point estimate of 10 cases per year was selected based on the ambient data of the Ambient Air Quality study.

Carbon Tetrachloride. Carbon tetrachloride was included as a pollutant of concern in thirteen studies (see Table B-8). Carbon tetrachloride sources are primarily point sources. At least eleven source categories were considered in the studies. The IEMP-Philadelphia and the South Coast studies incorporated both ambient measured concentrations and modeled ambient concentrations. Since carbon tetrachloride remains in the atmosphere long after it is emitted, ambient-measured concentrations are more likely to result in better risk estimates than those estimates based on modeled ambient concentrations. Therefore, the analysis only focuses on the ambient-measured cancer risk estimates.

Several comprehensive studies[6] have identified a global background concentration for carbon tetrachloride of approximately 0.8 $\mu g/m^3$. As carbon tetrachloride is difficult to measure and as there are no known "sinks" for carbon tetrachloride, any ambient-measured concentration much below this level must be viewed as due to test method error. This information is important in assessing the cancer risk for carbon tetrachloride as reported in the studies.

Ambient Estimates. Six studies estimated risk based on ambient-measured concentrations. The Ambient Air Quality study was based on data from 24 counties. The Ambient Air Quality study estimated a cancer rate of 0.15 cancer cases per year per million population, based

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[6] P.G. Simmonds et. al. "The Atmospheric Lifetime Experiment 6-Results for Carbon Tetrachloride Based on 3 Years Data." The Journal of Geophysical Research. Vol. 88, No. C13., pp. 8427-8441. October 20, 1983.

H.B. Singh, L.J. Falas, R.E. Stiles. "Selected Manmade Halogenated Chemicals in the Air and Oceanic Environment." The Journal of Geophysical Research. Vol. 88, No. C6, pp. 3675-3683. April 20, 1983.

H.B. Singh et. al. Toxic Chemicals in the Environment: A Program of Field Measurements. EPA/600/3-86-047. August 1986.

TABLE B-8

ESTIMATED ANNUAL CANCER CASES FROM CARBON TETRACHLORIDE BY SOURCE CATEGORY

SOURCE CATEGORY	INDIVIDUAL STUDY							
	Ambient Air Quality	NESHAP/ ATERIS	Drinking Water Aerators	POTW's	TSDF's	Thirty-five County	Five City	IEMP-Baltimore
Pesticide Production		0.42 (0.0018)						
Pharmaceutical Production		0.00013 (0.0000005)						
Chemical Users and Producers		0.19 (0.0008)					0.01 (0.00063)	X
Aerators			<0.0047 (<0.00002)					
POTW's				0.03 (0.00013)		0.13 (0.0027)		X
TSDF'S					2.28 (0.0095)			
Unspecified							0.44 (0.028)	
Indirect[d] Impacts								
Area		13.9[e] (0.058)						
TOTALS								
MODELED		14.5 (0.06)	<0.0047 (0.00002)	0.03 (0.00013)	2.28 (0.0095)	0.13 (0.0027)	0.46 (0.029)	
AMBIENT	36 (0.15)							0.3 (0.196)

TABLE B-8 -- concluded

ESTIMATED ANNUAL CANCER CASES FROM CARBON TETRACHLORIDE BY SOURCE CATEGORY

SOURCE CATEGORY	INDIVIDUAL STUDY					NATIONWIDE	
	IEMP-Kanawha Valley	IEMP-Philadelphia	IEMP-Santa Clara	Southeast Chicago	South Coast	RANGE[a]	POINT ESTIMATE[b]
Pesticide Production						0.42	0.42
Pharmaceutical Production			x			0.00013	0.00013
Chemical Users and Producers	0.0086-0.021 (0.086-0.214)					0.16-0.19[c]	0.19
Aerators						<0.0047	<0.0047
POTW's						0.03-0.65	0.03
TSDF'S				0.00014 (0.00036)		2.3	2.3
Unspecified				negligible		6.7	6.7
Indirect Impacts				0.064 (0.164)		--	--
Area						13.9	13.9
TOTALS							
MODELED	0.0086-0.021 (0.086-0.214)	0.035 (0.02)		0.00014 (0.00036)	0.0014 (0.00013)	23.5-24.2	24
AMBIENT		0.64 (0.39)	0.2 (0.14)	0.064 (0.164)	1.41 (0.13)	31.2-47[f]	41[g]

Footnotes to Table B-8.

NOTE: Numbers in parentheses are annual cancer cases per million population. For nationwide studies, annual cancer cases were divided by 240 million, unless otherwise noted. For studies with smaller geographic scopes, the annual cancer cases were divided by the study's population.

[a] The numbers in this column were calculated by taking the lowest and highest incidence rates for a source category and multiplying it by 240 (1986 U.S. population in millions). The total for this column is the summation of the low end of the range and the sum of the high end of the range.

[b] The numbers in this column present the results of the reduction analyses. In most instances, a point estimate of nationwide annual cancer incidence was derived for each pollutant/source category combination. In some instances, a point estimate could not be reasonably derived. For these instances, as narrow a range as possible of nationwide annual cancer incidence was estimated, and such ranges appear in this column. The text discusses how these point estimates and ranges were derived.

[c] Does not include extrapolating the incidence rate from the IEMP-Kanawha Valley study to a nationwide risk estimate because of the unknown type of facilities.

[d] "Indirect impacts" refers to carbon tetrachloride emissions that have been emitted in the past. As noted in the text, carbon tetrachloride persists in the atmosphere long after it has been emitted. Since the Southeast Chicago study used ambient-measured concentrations to estimate risk from this source category, the results are reported under the "Ambient" total and not under the "Modeled" totals.

[e] Incudes solvent applications and grain fumigation.

[f] Due to the minimal number of data points associated with the IEMP-Philadelphia study, the range does not include extrapolating nationwide cancer risk from the incidence rate for that study.

[g] As discussed in the text, this is based on a global background concentration of 0.8 $\mu g/m^3$.

on population-weighted ambient concentrations of 0.79 $\mu g/m^3$ for urban areas and 0.4 $\mu g/m^3$ for rural areas. The range of concentrations identified in the study was from 0 to 1.87 $\mu g/m^3$. The other five studies were for specific locales - Baltimore, Philadelphia, the South Coast Air Basin, Santa Clara, and Southeast Chicago. Of these five studies, the IEMP-Philadelphia study appears to be based on a single data point. Ambient-measured concentrations were 1.8 $\mu g/m^3$ for the IEMP-Philadelphia study. The Southeast Chicago study had two sets of sample data for two sample sites. One set measured 0.44 $\mu g/m^3$ over 10 to 15 samples and the second set measures 2.7 $\mu g/m^3$ for 5 to 7 samples. The IEMP-Baltimore study had at least 10 monitoring sites, and the South Coast study had five monitoring sites with a combined total of over 100 samples. The 10 sites in the IEMP-Baltimore study showed a range of average concentrations from 0.6 to 1.4 $\mu g/m^3$ with a population weighted average of 0.9 $\mu g/m^3$. The South Coast study showed annual (1985) average concentrations ranging from 0.6 to 0.76 $\mu g/m^3$ for the five sites and a population weighted average of 0.69 $\mu g/m^3$. The Santa Clara study reported monitored concentrations ranging from 0.2 to 1.2 $\mu g/m^3$ from a single monitoring site.

As seen above, the various studies present a range of carbon tetrachloride concentrations. A number of reported ambient-measured concentrations were substantially below the expected background concentration of 0.8 $\mu g/m^3$. Such instances are likely due to sampling error. Based on a concentration of 0.8 $\mu g/m^3$, a nationwide estimate of approximately 41 cancer cases per year (0.17 cancer cases per year per million population) is obtained. This result is very close to that estimated by four of the five studies. Only the IEMP-Philadelphia study shows a substantial deviation, with an estimated cancer rate of 0.39

cancer cases per year per million population. This could be due to sampling error, the small number of data points, geographical variation, or a combination of any of these factors.

Point Estimate. It appears that the best estimate of nationwide cancer risk from carbon tetrachloride is based on applying the background concentration to the total U.S. population, which results in an estimated cancer risk of 41 cancer cases per year. The studies indicate that there can be locally high levels of concentrations to which populations are exposed. This would increase the estimate of nationwide cancer risk based only on the background concentration of 0.8 $\mu g/m^3$. The magnitude of this potential increase, however, is unknown. Thus, nationwide cancer risk from carbon tetrachloride is estimated to be 41 cancer cases per year.

Chloroform. Thirteen studies included chloroform as a pollutant of concern (see Table B-9). Only a few specific source categories were identified as chloroform emission sources in these thirteen studies. One study, the South Coast study, found that ambient measured concentrations of chloroform were much higher than the modeled ambient concentrations, and suggested that this might be due to sources not included in the emission inventory. Thus, as was for carbon tetrachloride, risk estimates based on ambient measurements may yield better estimates. In addition, the non-specificity of a number of the studies as to the specific source categories examined made it difficult to sum across the estimates based on modeling.

Ambient Estimates. Three studies used ambient monitoring data to estimate cancer risk - the IEMP-Baltimore study, the South Coast study, and the Ambient Air Quality study. The IEMP-Baltimore study showed an average cancer rate of 0.29 cancer cases per year per million population, with a range for individual geographic areas within the city from 0.07 to 1.54 cancer cases per year per million population. Ambient measured concentrations ranged from 0.2 to 4.7 $\mu g/m^3$, with an average concentration of 1.7 $\mu g/m^3$ over the ten monitoring sites. The population weighted average, however, was approximately one-half of that, being 0.88 $\mu g/m^3$.

In the South Coast study, ambient concentrations from five monitoring sites ranged from 0.27 to 0.55 $\mu g/m^3$, for a population-weighted annual average of approximately 0.38 $\mu g/m^3$. This concentration is slightly less than one-half of Baltimore's population-weighted average concentration of 0.88 $\mu g/m^3$. The resulting cancer rate in the South Coast study was approximately 0.12 cancer cases per year per million population.

TABLE B-9

ESTIMATED ANNUAL CANCER RISK FROM CHLOROFORM BY SOURCE CATEGORY

SOURCE CATEGORY	INDIVIDUAL STUDY								
	Ambient Air Quality	NESHAP/ ATERIS	POTWs	Sewage Sludge Incinerators	TSDFs	Thirty-five County	Five City	IEMP-Baltimore	IEMP-Kanawha Valley
Pharmaceutical Manufacturing		0.16 (0.0007)							
Pulp and Paper		2.06 (0.0086)							
Chemical Users and Producers		0.21 (0.00088)					0.017 (0.001)		0.058-0.19 (0.58-1.9)
TSDFs					0.98 (0.004)				
Sewage Sludge Incinerators				0.10 (0.0004)					
POTWs			0.3 (0.001)			0.89 (0.004)			
Unspecified							0.186 (0.012)		
Chlorinated Drinking Water									
TOTALS									
MODELED		2.4 (0.01)	0.3 (0.001)	0.10 (0.0004)	0.98 (0.004)	0.89 (0.004)	0.2 (0.013)		0.058-0.19 (0.58-1.9)
AMBIENT	115 (0.48)							0.45 (0.29)	

TABLE B-9 -- concluded

ESTIMATED ANNUAL CANCER RISK FROM CHLOROFORM BY SOURCE CATEGORY

SOURCE CATEGORY	INDIVIDUAL STUDY				NATIONWIDE	
	IEMP-Philadelphia	IEMP-Santa Clara	Southeast Chicago	South Coast	RANGE[a]	POINT ESTIMATE[b]
Pharmaceutical Manufacturing	0.0088 (0.0053)				0.16-1.3	0.16
Pulp and Paper					2.1	2.1
Chemical Users and Producers					0.2-0.4[c]	0.2
TSDFs			negligible		0-1	1
Sewage Sludge Incinerators					0.1	0.1
POTWs	0.0013 (0.00077)		negligible		0-1	0.3
Unspecified			negligible		0-2.9[d]	--
Chlorinated Drinking Water			0.0029 (0.007)		1.7	1.7
TOTALS						
MODELED	0.001 (0.006)	0.001 (0.0007)	0.0029 (0.007)		4.2-10.4	5.6
AMBIENT				1.3 (0.12)	29-115	115

Footnotes to Table B-9.

NOTE: Numbers in parentheses are annual cancer cases per million population. For nationwide studies, annual cancer cases were divided by 240 million, unless otherwise noted. For studies with smaller geographic scopes, the annual cancer cases were divided by the study's population.

[a] The numbers in this column were calculated by taking the lowest and highest incidence rates for a source category and multiplying it by 240 (1986 U.S. population in millions). The total for this column is the summation of the low end of the range and the sum of the high end of the range.

[b] The numbers in this column present the results of the reduction analyses. In most instances, a point estimate of nationwide annual cancer incidence was derived for each pollutant/source category combination. In some instances, a point estimate could not be reasonably derived. For these instances, as narrow a range as possible of nationwide annual cancer incidence was estimated, and such ranges appear in this column. The text discusses how these point estimates and ranges were derived.

[c] Does not include extrapolating the incidence rates from the IEMP-Kanawha Valley study to nationwide cancer risk estimates because of the uncertainty as to the type of facilities being modeled. Low end of range assumes the risk is duplicative of the NESHAP/ATERIS risk estimate. High end of range assumes risk is independent of the NESHAP/ATERIS risk estimate, and sums the two together.

[d] A lower end range of 0 is given because it is possible that the risk estimate in the 5-City study is duplicative of risk from other specified source categories.

The Ambient Air Quality study used ambient measurement data from 22 geographic areas, the majority of which were located in California. The annual average ambient concentrations ranged from 0 to 9.3 $\mu g/m^3$. The California data has a much narrower range (0.13 to 1.81 $\mu g/m^3$), and a much lower average concentration than the non-California data. Using a population weighted urban concentration of 1.86 $\mu g/m^3$ and a rural concentration of 0.1 $\mu g/m^3$, the Ambient Air Quality study estimated total annual cancer cases at 115, or equivalently 0.48 cancer cases per year per million population. Of the three studies using ambient-measured concentrations, the Ambient Air Quality study was selected as providing the best estimate of nationwide annual incidence because of its broader geographic coverage.

Modeled Estimates. Excluding the "chemical manufacturing" source category in the IEMP-Kanawha Valley study for the moment, the modeled estimates of cancer risk from chloroform are estimated to be between 4 and 10 cancer cases per year nationwide. (This supports the South Coast study's finding that models may be "missing" chloroform emission sources when compared to the cancer risk estimates based on ambient-measured concentrations.) The "chemical manufacturing" source category in the IEMP-Kanawha Valley study has a very high cancer rate - 0.58 to 1.9 cancer cases per year per million population. However, it does not appear reasonable at this time to try to extrapolate nationwide cancer risks from this annual cancer incidence per million population because the types of facilities and their products that lead to these chloroform emissions have not been identified. Thus, the representativeness of the emission sources is unknown.

Point Estimate. As noted above, ambient measurements appear to provide a more complete accounting of chloroform concentrations then do modeled estimates. The cancer risks based on ambient-measured concentrations, therefore, were selected as being more likely representative of actual risks. Of the three studies that estimated cancer risk from ambient-measured concentrations, the Ambient Air Quality study used data with a broad geographic coverage, including data from areas covered by the two other studies. Therefore, the estimate of 115 cancer cases per year from the Ambient Air Quality study was selected as estimate of nationwide cancer risk from exposure to chloroform emissions.

Chromium. Thirteen studies included chromium as a pollutant of concern (see Table B-10 and B-11). Ten of the studies estimated cancer risk based on modeled ambient concentrations; four using ambient measured concentrations. (The South Coast study used both modeled and monitored ambient concentrations to estimate risk.) Of the fourteen plus source categories identified, two are of primary concern - chrome platers and cooling towers - for estimating cancer risk. For both modeled and ambient measured concentrations, the percent of total chromium assumed to be hexavalent is also important. For some source categories, such as chrome platers, nearly 100 percent of total chromium emissions are hexavalent; while for some other source categories, such as incinerators, less than 1 percent of total chromium emissions are hexavalent.

Ambient Estimates. Assuming 100 percent of the measured ambient concentrations are hexavalent, the four studies resulted in estimated cancer rates between 0.82 and 2.77 cancer cases per year per million population (see Table B-10). On a nationwide basis, this is equal to approximately 197 to 665 cancer cases per year.

Results from the 5-City study suggest that the ratio of hexavalent to total chromium concentrations in model-predicted ambient levels range from 0.085 to 0.815. Applying the appropriate ratios to the annual cancer incidences per million population in Table B-10 to the IEMP-Baltimore study and the South Coast study yields very similar cancer rates - 0.8 vs. 0.67 cancer cases per year per million population. For the five cities, an arithmetic average ratio of 0.4 and a population-weighted average of 0.6 for hexavalent-to-total chromium emissions were obtained. Applying these ratios to the Ambient Air Quality estimate of 283 cancer cases per year yield an estimated 113 and 175 cancer cases

TABLE B-10

ESTIMATED ANNUAL CANCER CASES FROM CHROMIUM BY SOURCE CATEGORY - AMBIENT MEASURED CONCENTRATIONS

STUDY	Concentration[a] (µg/m3)	Incidence Annual	Incidence Annual Per Million Population	Nationwide Incidence	Point Estimate
Ambient Air Quality					
100% Hexavalent	0.0069	283	1.18	283	
62% Hexavalent	0.0043	175	0.73	175	
40% Hexavalent	0.0028	113	0.47	113	
IEMP - Santa Clara					
100% Hexavalent	0.0126-0.0138	3.02-3.3	2.16-2.37	518-569	
IEMP - Baltimore					
100% Hexavalent	0.016	4.24	2.77	665	
29% Hexavalent			0.8	192	
South Coast					
100% Hexavalent	0.0048	8.97	0.82	197	
81.5% Hexavalent			0.67	161	
Totals					
100% Hexavalent				197-665	283
<100% Hexavalent				113-192	113

[a] Total chromium.

TABLE B-11

ESTIMATED ANNUAL CANCER CASES FROM CHROMIUM - MODELED CONCENTRATIONS

	INDIVIDUAL STUDY						
SOURCE CATEGORY	NESHAP/ ATERIS	Coal and Oil Combustion	Hazardous Waste Combustion	Municipal Incinerators	Waste Oil Combustion	Thirty-five County	Five City
BOPF's	0.001 (0.000004)						
Chemicals	0.22 (0.00091)						
Chromite	0.00045 (0.000002)						
Cooling Towers	0.58 (0.0024)					0.0018 (0.00004)	7.37 (0.464)
Ferrochromium Production	0.062 (0.00026)						
Glass Furnaces	0.013 (0.000054)						x
Municipal Incinerators	0.00071 (0.000003)			0.12 (0.0005)			
Refractories	0.016 (0.000067)						0.44 (0.028)
Sewage Sludge Incinerators	0.00016 (0.0000007)						
Specialty Steel	0.25 (0.001)						0.00089 (0.00006)
Heating/ Combustion		0.20 (0.0008)				0.06 (0.0013)	0.0052 (0.00033)
Hazardous Waste Combustors			<0.25 (<0.001)				
Waste Oil Combustors					0.0012-0.0065 (<0.000027)	0.01 (0.0002)	
Chrome platers	x					273 (5.77)	8 (0.5)
Unspecified							
Other	330^d (1.38)						
Motor Vehicles							
TOTALS	331 (1.38)	0.20 (0.0008)	<0.25 (<0.001)	0.12 (0.0005)	0.0012-0.0065 (<0.000027)	273.4 (5.78)	15.81 (1.00)

TABLE B-11 -- concluded

ESTIMATED ANNUAL CANCER CASES FROM CHROMIUM - MODELED CONCENTRATIONS

SOURCE CATEGORY	INDIVIDUAL STUDY			NATIONWIDE	
	Sewage Sludge Incinerators	Southeast Chicago	South Coast	RANGE[a]	POINT ESTIMATE[b]
BOPF's		x		0.001	0.001
Chemicals				0.22	0.22
Chromite				0.0045	0.0045
Cooling Towers		<0.024 (0.062)		0.01-111	0.01-111
Ferrochromium Production				0.062	0.062
Glass Furnaces		x		0.013	0.013
Municipal Incinerators				0.00071-0.12	0.12
Refractories				0.02-6.7	0.02-6.7
Sewage Sludge Incinerators	0.26 (0.0011)			.00016-0.26	0.26
Specialty Steel		0.00086 (0.0022)		0.01-0.53	0.01-0.53
Heating/ Combustion		x		0.08-0.3	0.2
Hazardous Waste Combustors				<0.25	<0.25
Waste Oil Combustors				0.0012-0.05	0.0012-0.05
Chrome platers		0.186 (0.473)		113-343[c]	120
Unspecified			6.97 (0.64)	154	--
Other				330	--
Motor Vehicles			1.17 (0.107)	26	26
TOTALS	0.26 (0.0011)	0.211 (0.537)	8.14 (0.75)	140-489[e]	147-265

Footnotes to Table B-11.

NOTE: Numbers in parentheses are annual cancer cases per million population. For nationwide studies, annual cancer cases were divided by 240 million, unless otherwise noted. For studies with smaller geographic scopes, the annual cancer cases were divided by the study's population.

NOTE: An "x" in a column indicates that the source category was considered in the study, but a specific cancer risk for the source category was not indicated.

[a] The numbers in this column were calculated by taking the lowest and highest incidence rates for a source category and multiplying it by 240 (1986 U.S. population in millions). The total for this column is the summation of the low end of the range and the sum of the high end of the range.

[b] The numbers in this column present the results of the reduction analyses. In most instances, a point estimate of nationwide annual cancer incidence was derived for each pollutant/source category combination. In some instances, a point estimate could not be reasonably derived. For these instances, as narrow a range as possible of nationwide annual cancer incidence was estimated, and such ranges appear in this column. The text discusses how these point estimates and ranges were derived.

[c] Based on adjusting estimated incidence from 272 to 191 based on newer emission data for one city (see text) and then extrapolating the 35-County study estimate nationwide according to information provided in the 35-County study, which indicates 55% of chrome platers are in 35 counties.

[d] Includes nine source categories: chrome plating, refractory, chromium chemicals, steel manufacturing, ferrochromium manufacturing, chromium ore manufacturing, sewage sludge incineration, municipal refuse incineration, and cement manufacturing. Over 90 percent of the annual cancer incidence is associated with refractory, chromium chemicals, chrome plating, and steel manufacturing.

[e] Does not include risk estimates from "unspecified" and "other" source categories.

per year respectively or, equivalently, cancer rates of approximately 0.47 and 0.73 cancer cases per year per million population.

Modeled Estimates. Summing across the various source categories results in a range of nationwide cancer cases between 140 and 489 per year. By far the majority of this range is due to the estimate for chrome platers (113 to 343 per year) and secondarily to cooling towers (0.01 to 111 per year).

The wide range of incidence from the chrome platers appears to be mostly due to the estimate of total chromium emissions attributable to chrome platers in one particular city. The 35-County study uses emissions approximately 4.2 times that used in the 5-City study. However, the higher level of emissions used in the 35-County study is apparently out-of-date. The 5-City study's data are more recent and are known to be in agreement with the local records for that city. Adjusting the 35-County study's estimate to the lower emissions used in the 5-City study, a new nationwide cancer rate of about 1.43 cancer cases per year per million population is calculated. This is still higher than the 5-City study's cancer rate of 0.5 cancer cases per year per million population. The Southeast Chicago study shows an annual cancer incidence per million population essentially equivalent to that of the 5-City study (0.47 vs. 0.5). For the best estimate of risk from chrome platers, the annual cancer incidence per million population from the 5-City study and the Southeast Chicago study (0.5 cancer cases per year per million population) was selected as the best estimate to extrapolate to a nationwide estimate of annual incidence.

The 35-County study and the 5-City study also show significantly different cancer rates for cooling towers (0.0004 vs. 0.46 cancer cases per year per million population). However, insufficient data are available to understand why such a difference exists.

Point Estimate. The range of cancer risks from the studies based on modeled ambient concentrations and those from the ambient measured studies are similar (147 to 265 vs. 197 to 665 cancer cases per year). Considering the ambient-based estimates only, the Ambient Air Quality study, by virtue of its broader geographic scope, may better reflect nationwide incidence. The Ambient Air Quality study would result in an upper estimate of about 283 cancer cases per year (at 100% hexavalent). By applying the results of the 5-City study as to estimated average ratio of hexavalent to total chromium to the Ambient Air Quality study's result, total cancer cases would be estimated to be 113 per year. Considering the modeled-based estimates, there does not seem to be sufficient information to further narrow the range (147 to 265).

Because of the uncertainty of applying a nationwide ratio of hexavalent to total chromium to ambient-measured data, the modeled estimates' range of 147 to 265 cancer cases per year was selected as the estimate of nationwide annual cancer incidence due to exposure to hexavalent chromium emissions.

Coke Oven Emissions. Three studies estimated cancer incidences from coke oven emissions - the NESHAP/ATERIS data base, the 35-County study, and the Southeast Chicago study (see Table B-12). Only the Southeast Chicago study identified estimated concentrations of coke oven emissions. The Southeast Chicago study estimated a range of concentrations from approximately 0 $\mu g/m^3$ to 6.1 $\mu g/m^3$. (That study noted that the actual peak concentration for coke oven pollutants is probably somewhat higher than the 6.1 $\mu g/m^3$.) The Southeast Chicago study estimated approximately 0.35 cancer cases per year for its study area. This is equivalent to an areawide average coke oven emissions concentration of approximately 0.1 $\mu g/m^3$. The other two studies show areawide average concentrations of approximately 0.005 $\mu g/m^3$ (35-County study) and 0.0033 $\mu g/m^3$ (NESHAP/ATERIS data base). This trend in calculated concentrations is expected since the area covered by the Southeast Chicago study is known to contain these emission sources and the counties in the 35-County study were selected, in part, on the basis of known emission sources. Thus, those two studies would be expected to result in higher cancer rates and estimated coke oven concentrations. The NESHAP/ATERIS data base is broadest in scope, including areas with and without coke oven emission sources, and was therefore selected as the estimate of cancer incidence from exposure to coke oven emissions (approximately 7 cancer cases per year).

TABLE B-12

ESTIMATED ANNUAL CANCER CASES FROM COKE OVEN EMISSIONS

SOURCE CATEGORY	INDIVIDUAL STUDY			NATIONWIDE	
	NESHAP/ ATERIS	Thirty-five County	Southeast Chicago	RANGE[a]	POINT ESTIMATE[b]
Iron and Steel	6.9 (0.029)	2.1 (0.044)	0.346 (0.88)	7-11[c]	7
TOTALS					
MODELED	6.9 (0.029)	2.1 (0.044)	0.346 (0.88)	7-11[c]	7

NOTE: Numbers in parentheses are annual cancer cases per million population. For nationwide studies, annual cancer cases were divided by 240 million, unless otherwise noted. For studies with smaller geographic scopes, the annual cancer cases were divided by the study's population.

[a] The numbers in this column were calculated by taking the lowest and highest incidence rates for a source category and multiplying it by 240 (1986 U.S. population in millions). The total for this column is the summation of the low end of the range and the sum of the high end of the range.

[b] The numbers in this column present the results of the reduction analyses. In most instances, a point estimate of nationwide annual cancer incidence was derived for each pollutant/source category combination. In some instances, a point estimate could not be reasonably derived. For these instances, as narrow a range as possible of nationwide annual cancer incidence was estimated, and such ranges appear in this column. The text discusses how these point estimates and ranges were derived.

[c] The range does not include the nationwide estimate that would be calculated using the incidence rate from the Southeast Chicago study, because it was felt that the concentration of iron and steel facilities in the Southeast Chicago study area was too non-representative of typical nationwide conditions.

1,2 Dichloropropane. Although two studies reported cancer risk for 1,2 dichloropropane, the IEMP-Baltimore study apparently applied the annual cancer incidence per million population generated in the IEMP-Philadelphia study (i.e., 0.067 cancer cases per year per million population) to the Baltimore population to estimate cancer risk. In the IEMP-Philadelphia study, the initial source of 1,2 dichloropropane is from an unspecified chemical manufacturing plant. Thus, it would be reasonable to apply the IEMP-Philadelphia annual cancer incidence per million population only in those instances where a similar facility exists. Since the type of facility is not reported, a reasonable nationwide estimate can not be made. Obviously, the IEMP-Philadelphia annual cancer incidence per million population could be applied to the total U.S. population to yield a nationwide estimate of 16 cancer cases per year. This estimate, however, has essentially no meaning. Thus, the best that can be done is to say that there are possibly as little as 0.2 cancer cases per year (in Philadelphia and Baltimore).

Dioxin. Five studies included dioxin as a pollutant of concern (see Table B-13). The risk estimates in each study are highly uncertain. The South Coast study used ambient data found in an article[7] because there were no currently available data on ambient concentrations of dioxins and furans in the South Coast study area. The South Coast study report notes that "these data have limited usefulness because the vapor phase concentrations of these pollutants were not measured."

Both the Southeast Chicago study and the Municipal Waste Combustor study examined dioxin emissions from incinerators. Both studies noted problems with estimating risk. For example, the Municipal Waste Combustor study identified two problems with estimating risk from dioxins. One problem dealt with the capture efficiency of the sampling method used to estimate emissions of dioxin and the other problem dealt with the methodology needed to extrapolate the risk from tetrachlorinated dibenzodioxin (TCDD) to the other dioxin subspecies.

The TSDF study presents a very rough initial estimate of potential risk from a large number of pollutants. By proportioning according to projected emissions and unit risk factors, cancer risk for each individual pollutant can be generated. When this is done, dioxin is calculated to contribute 91 of the estimated 140 cancer cases from TSDFs. This estimate must be viewed as a very crude estimate. In fact, there may be substantially less dioxin emitted from TSDFs so that the actual risk is much lower.

Point Estimate. For dioxin, it is extremely difficult to identify a point estimate because of the "limited usefulness" of the ambient data

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[7] Czuczwa, J. and R.A. Hites, 1984. "Environmental Fate of Combustion Generated Polychlorinated Dioxins and Furans," Environ. Sci. Technol. 18(6):444-50.

TABLE B-13

ESTIMATED ANNUAL CANCER CASES FROM DIOXIN BY SOURCE CATEGORY

SOURCE CATEGORY	INDIVIDUAL STUDY					NATIONWIDE	
	Municipal Waste Combustors	Sewage Sludge Incinerator	TSDFs	Southeast Chicago	South Coast	RANGE[a]	POINT ESTIMATE[b]
TSDFs			91 (0.38)	0.00014 (0.00036)		0.09-91	0.09-91
Sewage Sludge Incinerators		0.42 (0.0013)				0.42	0.42
Municipal Waste Combustors	1-20[c] (0.004-0.083)		0.0029 (0.0073)			1-20	1-20
TOTALS							
MODELED	1-20 (0.004-0.083)	0.42 (0.0013)	91 (0.38)	0.003 (0.0076)		2-111	2-111
AMBIENT					0.29-5.71 (0.026-0.52)	6-125	6-125

NOTE: Numbers in parentheses are annual cancer cases per million population. For nationwide studies, annual cancer cases were divided by 240 million, unless otherwise noted. For studies with smaller geographic scopes, the annual cancer cases were divided by the study's population.

[a] The numbers in this column were calculated by taking the lowest and highest incidence rates for a source category and multiplying it by 240 (1986 U.S. population in millions). The total for this column is the summation of the low end of the range and the sum of the high end of the range.

[b] The numbers in this column present the results of the reduction analyses. In most instances, a point estimate of nationwide annual cancer incidence was derived for each pollutant/source category combination. In some instances, a point estimate could not be reasonably derived. For these instances, as narrow a range as possible of nationwide annual cancer incidence was estimated, and such ranges appear in this column. The text discusses how these point estimates and ranges were derived.

[c] This estimate is based on an older assessment and is calculated by applying the ratio of the newer total risk estimate to the older total risk estimate. See the summary on municipal waste combustors in Appendix C.

and the great uncertainty associated with the modeled estimates. Therefore, the nationwide estimate of annual cancer incidence from exposure to dioxin is a range, from approximately 2 to 125 cancer cases per year nationwide. Even this range remains very crude and this caveat should be kept in mind.

Ethylene dibromide. Ten studies included ethylene dibromide (EDB) (1,2-dibromoethane) as a pollutant of concern (see Table B-14). Sources of EDB in these ten studies included motor vehicles, drinking water aerators, gasoline marketing (service stations, refueling, bulk plants and terminals), TSDFs, and EDB manufacturing and formulation facilities. EDB is used in leaded gasoline as a "scavenger," and as leaded gasoline is phased-out, EDB emissions will be reduced. Two studies used ambient measured concentrations to estimate risk, and eight used modeled concentrations. (The South Coast study used both ambient measured and modeled concentrations.)

Modeled Estimates. As seen in Table 3-23, the estimate of annual cancer cases per million population varies dramatically for the gasoline marketing source category. There is a 1,000-fold difference (0.038 vs. 0.000033) in this estimate. This could be explained, in part, as the NESHAP/ATERIS data base's estimate is based on a July 1978 report[8], whereas the Gasoline Marketing study is a more recent study. Furthermore, the Gasoline Marketing study's estimate is based on a 33-year projection period in which EDB emissions fall to zero for the last 20 to 23 years due to the projected complete phase-out of leaded gasoline. Considering its focused subject area and the explicit accounting of the projected phase out of EDB as a gasoline additive, the estimate of cancer incidence from the Gasoline Marketing study was selected as the best estimate of cancer risk from gasoline marketing for EDB emissions.

For motor vehicles, the range of cancer incidence per million population is narrower, from almost 0.002 to 0.011 annual cancer cases

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[8] Mara, Susan J, and Shonh S. Lee, Atmospheric Ethylene Dibromide: A Source-Specific Assessment, SRI International, July 1978.

TABLE B-14

ESTIMATED ANNUAL CANCER CASES FROM ETHYLENE DIBROMIDE BY SOURCE CATEGORY

SOURCE CATEGORY	INDIVIDUAL STUDY							
	Ambient Air Quality	NESHAP/ ATERIS	Drinking Water Aerators	Gasoline Marketing	Mobile Sources	TSDFs	IEMP- Kanawha Valley	IEMP- Santa Clara
Gasoline Marketing		9.2 (0.038)		0.008 (0.000033)			0.0003 (0.0028)	
Drinking Water Aerators			<0.0002[c] (<0.000001)					
Motor Vehicles		x			0.78 (0.004)		0.0011 (0.011)	
TSDFs						0.02 (0.0008)		
EDB Mfg. and Formulation		x						
TOTALS								
MODELED		11.5 (0.048)	<0.0002 (<0.000001)	0.008 (0.000033)	0.78 (0.004)	0.02 (0.0008)	0.0013 (0.013)	0.004 (0.003)
AMBIENT	68 (0.28)							

TABLE B-14 -- concluded

ESTIMATED ANNUAL CANCER CASES FROM ETHYLENE DIBROMIDE BY SOURCE CATEGORY

SOURCE CATEGORY	INDIVIDUAL STUDY		NATIONWIDE	
	Southeast Chicago	South Coast	RANGE[a]	POINT ESTIMATE[b]
Gasoline Marketing			0.008-9.2	0.008
Drinking Water Aerators			<0.0002[c]	<0.0002[c]
Motor Vehicles	0.00071 (0.0018)	0.02 (0.002)	0.44-2.64	0.78
TSDFs			0.02	0.02
EDB Mfg. and Formulation			<2.3	1.5[d]
TOTALS				
MODELED	0.00071 (0.0018)	0.02 (0.002)	0.5-14	2.3
AMBIENT		1.13 (0.104)	25-68	68

NOTE: Numbers in parentheses are annual cancer cases per million population. For nationwide studies, annual cancer cases were divided by 240 million, unless otherwise noted. For studies with smaller geographic scopes, the annual cancer cases were divided by the study's population.

NOTE: An "x" in a column indicates that the source category was considered in the study, but a specific cancer risk for the source category was not indicated.

[a] The numbers in this column were calculated by taking the lowest and highest incidence rates for a source category and multiplying it by 240 (1986 U.S. population in millions). The total for this column is the summation of the low end of the range and the sum of the high end of the range.

[b] The numbers in this column present the results of the reduction analyses. In most instances, a point estimate of nationwide annual cancer incidence was derived for each pollutant/source category combination. In some instances, a point estimate could not be reasonably derived. For these instances, as narrow a range as possible of nationwide annual cancer incidence was estimated, and such ranges appear in this column. The text discusses how these point estimates and ranges were derived.

[c] The Drinking Water Aerator study estimated 0.0002 annual cancer cases from EDB and dibromochloropropane combined. No separate estimate for EDB was given.

[d] Assumes 0.003 cancer cases per year per million population is due to motor vehicles and the remainder (0.0063) is from EDB manufacturing and formulation.

per million population. These estimates translate into total nationwide cancer cases of approximately 0.5 to 2.6 per year. Considering again the specific source nature of the Mobile Source study, the best estimate of cancer risk from mobile sources for EDB emissions was selected from the Mobile Sources study (0.78 cancer cases per year nationwide). Cancer cases from TSDFs and drinking water aerators appear to be negligible. The estimates of cancer risk from EDB manufacturing and formulation and from motor vehicles in the NESHAP/ATERIS data base could not be "broken out" from the NESHAP/ATERIS data base's total.

When combined, the above data result in a potential cancer rate range of 0.002 to 0.056 cancer cases per year per million population (or 0.5 to 14 annual cancer cases nationwide), with a best estimate of 2.4 cancer cases per year nationwide. The best estimate includes 1.5 cancer cases per year nationwide from EDB manufacturing and formulation facilities. This estimate was obtained by subtracting the best estimate of cancer risk from motor vehicles (0.78 cancer cases per year) from the NESHAP/ATERIS data base's estimated 2.3 cancer cases per year from motor vehicles plus EDB manufacturing and formulation facilities.

Ambient Estimates. Two studies used ambient measured concentrations to estimate risk from EDB - the South Coast study and the Ambient Air Quality study. The South Coast study measured annual EDB concentrations at five locales, ranging from 0.0154 to 0.0616 $\mu g/m^3$ in 1985, with a population weighted annual average concentration between 0.021 and 0.048 $\mu g/m^3$. These concentrations were substantially higher than the modeled concentrations. The South Coast study suggested that this discrepancy might be due to entrainment and out-gassing from the ground, which would increase the ambient measured concentrations relative to the modeled ambient concentrations.

The Ambient Air Quality study used ambient data available from 30 locations. In 29 of the 30 locations, concentrations ranged from 0.03 to 0.09 $\mu g/m^3$, with one location reporting a concentration of 0.2 $\mu g/m^3$. Most of the data was for California locations, which were measured in 1986 and 1987. Calculating cancer cases in California based on the California ambient measured concentrations (0.03 to 0.1 $\mu g/m^3$) and population and in the rest of the U.S. based on the non-California ambient measured concentrations (0.04 to 0.02 $\mu g/m^3$) and population, the Ambient Air Quality study estimated 68 annual cancer cases nationwide. This is equivalent to the cancer risk calculated from population weighted concentrations of 0.10 $\mu g/m^3$ for urban populations and 0.05 $\mu g/m^3$ for rural populations.

Point Estimate. The consistency of the ambient measured concentrations suggests that the studies that modeled EDB concentrations did not fully account for all sources of EDB emissions, whether they occur from entrainment or outgassing, as suggested in the South Coast study, or for some other reason. The ambient measured concentrations, thus, seem to be a preferable basis for estimating risk. The concentrations measured in the South Coast Air Basin (0.021 to 0.048 $\mu g/m^3$) are very similar to the California data used in the Ambient Air Quality study (0.03 to 0.1 $\mu g/m^3$). Given the broader geographic scope of the Ambient Air Quality study, the results from that study (68 cancer cases per year nationwide) were selected as the estimate of cancer incidence from exposure to EDB emissions.

Ethylene dichloride. Ethylene dichloride (EDC) (1,2-dichloroethane) emissions come from both point and area sources. Point sources of EDC include the production of EDC, vinyl chloride, methyl chloroform (CHC), ethylamines, trichloroethylene, perchloroethylene, vinylidene chloride, ethyl chloride, polysulfide rubber, and liquid pesticide. Area source emissions include grain fumigation, leaded gasoline, paints, coatings, adhesives, cleaning solvents, and waste treatment, storage, and disposal facilities.[9]

Thirteen studies included EDC as a pollutant of concern (see Table B-15). At least thirteen source categories were specified in these studies. The cancer risk estimates in the Ambient Air Quality study and the IEMP-Baltimore study were based on ambient measured concentrations. The IEMP-Philadelphia study compared ambient measured concentrations with modeled ambient concentrations. The IEMP-Philadelphia study and the remaining ten other studies used models to estimate cancer risk.

Ambient Estimates. The Ambient Air Quality study used an urban average concentration of 0.59 $\mu g/m^3$ and a rural average concentration of 0.20 $\mu g/m^3$ to estimate cancer risk. EDC concentration data from 17 locations were used, with a range of concentration from 0.09 to 4.12 $\mu g/m^3$. The IEMP-Baltimore study measured annual average ambient concentrations ranging from 0.2 to 2.6 $\mu g/m^3$, with a population weighted annual average concentration of 0.26 $\mu g/m^3$. The IEMP-Baltimore study data falls within the range used in the Ambient Air Quality study. Since the higher ambient concentrations in the Ambient Air Quality study seem to correspond to cities with known point sources of EDC emissions

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[9] U.S. EPA. Locating and Estimating Air Emissions from Sources of Ethylene Dichloride. EPA-450/4-84-007d. March 1984.

TABLE B-15

ESTIMATED ANNUAL CANCER CASES FROM ETHYLENE DICHLORIDE BY SOURCE CATEGORY

SOURCE CATEGORY	INDIVIDUAL STUDY					
	Ambient Air Quality	NESHAP/ ATERIS	Drinking Water Aerators	Gasoline Marketing	POTWs	TSDFs
Pesticide Production		0.01 (0.00004)				
POTWs					0.09 (0.0004)	
Pharmaceutical Manufacturing		0.0029 (0.000012)				
EDC Production		0.79 (0.0033)				
CHC Users		0.0044 (0.000018)				
Drinking Water Aerators			x			
Gasoline Marketing				0.01 (0.00004)		
TSDFs						5.37 (0.024)
Unspecified Point Sources						
Chemical Manufacturing						
Refineries						
Sewer Volatilization						
Delaware River						
Motor Vehicles						
TOTALS						
MODELED		0.81 (0.0034)	negligible	0.01 (0.00004)	0.09 (0.0004)	5.37 (0.024)
AMBIENT	45 (0.19)					

TABLE B-15 -- continued

ESTIMATED ANNUAL CANCER CASES FROM ETHYLENE DICHLORIDE BY SOURCE CATEGORY

SOURCE CATEGORY	Thirty-five County	Five City	IEMP-Baltimore	IEMP-Kanawha Valley	IEMP-Philadelphia	Southeast Chicago
Pesticide Production						
POTWs	4.62 (0.098)				0.083 (0.05)	negligible
Pharmaceutical Manufacturing						
EDC Production						
CHC Users						
Drinking Water Aerators						
Gasoline Marketing	0.12 (0.003)	0.013 (0.0008)		0.00035 (0.0035)	0.00087 (0.00052)	
TSDFs						negligible
Unspecified Point Sources	1.25 (0.026)	0.814 (0.051)		0.00002 (0.0002)		0.00071 (0.0018)
Chemical Manufacturing		0.009 (0.0005)			0.00004 (0.000024)	
Refineries					0.011 (0.0066)	
Sewer Volatilzation					0.019 (0.011)	
Delaware River					0.022 (0.013)	
Motor Vehicles						
TOTALS						
MODELED	5.99 (0.127)	0.83 (0.052)		0.00037 (0.0037)	0.138 (0.083)	0.00071 (0.0018)
AMBIENT			0.148 (0.097)			

TABLE B-15 -- concluded

ESTIMATED ANNUAL CANCER CASES FROM ETHYLENE DICHLORIDE BY SOURCE CATEGORY

		NATIONWIDE	
SOURCE CATEGORY	South Coast	RANGE[a]	POINT ESTIMATE[b]
Pesticide Production		0.01	0.01
POTWs		0.1-24	0.1
Pharmaceutical Manufacturing		0.0029	0.003
EDC Production		0.79	0.79
CHC Users		0.0044	0.0044
Drinking Water Aerators		negligible	negligible
Gasoline Marketing		0.01-0.84	0.01
TSDFs		5.37	5.4
Unspecified Point Sources	x	0-12.2	0-12.2
Chemical Manufacturing		0.007-0.12	0.1
Refineries		1.92	1.92
Sewer Volatilzation		3.36	3.36
Delaware River		3.84	3.84
Motor Vehicles		0-0.17	<0.2
TOTALS MODELED	0.007 (0.0007)	15.4-52.5	16-28
AMBIENT		23.3-45	45

Footnotes to Table B-15.

NOTE: Numbers in parentheses are annual cancer cases per million population. For nationwide studies, annual cancer cases were divided by 240 million, unless otherwise noted. For studies with smaller geographic scopes, the annual cancer cases were divided by the study's population.

NOTE: An "x" in a column indicates that the source category was considered in the study, but a specific cancer risk for the source category was not indicated.

[a] The numbers in this column were calculated by taking the lowest and highest incidence rates for a source category and multiplying it by 240 (1986 U.S. population in millions). The total for this column is the summation of the low end of the range and the sum of the high end of the range.

[b] The numbers in this column present the results of the reduction analyses. In most instances, a point estimate of nationwide annual cancer incidence was derived for each pollutant/source category combination. In some instances, a point estimate could not be reasonably derived. For these instances, as narrow a range as possible of nationwide annual cancer incidence was estimated, and such ranges appear in this column. The text discusses how these point estimates and ranges were derived.

the lower concentrations in Baltimore could reflect the lack of such sources.

On the basis of its wider geographic scope and its coverage of cities with and without known point sources, the results from the Ambient Air Quality study seem to provide a better estimate of nationwide cancer risk from EDC than does the IEMP-Baltimore study.

Modeled Estimates. Unlike the results for many other compounds, there appears to be very good agreement as to the risk from EDC between the estimates based on modeled versus measured ambient concentrations. As seen in Table B-15, when the various individual source categories are summed, the range of nationwide risks is nearly identical to the range based on the two studies using ambient measured concentrations.

The major difficulty in summing the source categories is the "unspecified point source" source category in the 35-County study. If this source category duplicates other specified source categories, then the range of nationwide cancer cases decreases from 15 to 53 per year to 3 to 40 per year. It is interesting to note that the total cancer rate of the 35-County study (0.127 cancer cases per year per million population) falls within the range created by the IEMP-Baltimore and the Ambient Air Quality studies (0.097 to 0.19 cancer cases per year per million population).

Of the individual source categories, the nationwide cancer risk associated with POTWs has the largest absolute difference. The POTW study shows a much lower cancer rate (0.0004 annual cancer cases per million population) than does either the IEMP-Philadelphia study (0.059 annual cancer cases per million population) or the 35-County study (0.098 annual cancer cases per million population). The causes for this wide difference are unknown. If the nationwide POTW study is assumed to more accurately reflect the exposure to EDC emissions from POTWs than the two smaller geographic studies, estimates of nationwide cancer risk would be between 15.4 and 28.6 cases per year. If the "unspecified point source" source category is also eliminated (as discussed above), the nationwide cancer cases decrease further, to 3.2 to 16.4 cases per year.

Three of the source categories (refineries, sewer volatilization, and Delaware River) are extrapolated from the IEMP-Philadelphia study to obtain nationwide cancer risk estimates. Whether this is reasonable is very uncertain. For example, while a large number of cities have petroleum refineries, they are better modeled on a site-specific basis than by applying the results of one city with two refineries to the nation as a whole.

Point Estimate. Overall, the results from the various studies are fairly close. The Ambient Air Quality study's result, 45 cancer cases per year, was selected as the estimate for nationwide cancer incidence from exposure to EDC on the basis of its wider geographic scope and greater likelihood of accounting for area-wide emission sources.

Ethylene oxide. Six studies estimated cancer risk from ethylene oxide (ETO) emissions (see Table B-16). The TSDF study also included ethylene oxide as a pollutant of concern, but no emissions of ethylene oxide where indicated and thus no risk was reported. Specific source categories include ETO production and commercial sterilization. All of the studies used modeled ambient concentrations to estimate risk.

Modeled Estimates. The six studies show a wide range of cancer rates, from approximately 0.02 to 8.4 annual cancer cases per million population. The IEMP-Kanawha Valley has the highest cancer rate, 3.5 or 8.4 cancer cases per year per million population, depending on which model is used. The 8.4 cancer rate is likely to be an overestimate because of the nature of the model. The sources of ethylene oxide in the Kanawha Valley are particular chemical manufacturing facilities. These facilities are not included in the NESHAP/ATERIS data base. In addition, the document "Locating and Estimating Emissions from Sources of Ethylene Oxide" (U.S. EPA, EPA-450/4-84-0071, September 1986) does not list any source in West Virginia. The high cancer rate is due to specific sources that may be unique to the Kanawha Valley. Even if not unique to the Kanawha valley, no information is available to extrapolate to obtain a nationwide estimate.

Except for the 5-City study and assuming the ATERIS file is the more accurate estimate of risk for commercial sterilizers under the NESHAP/ATERIS data base, the remaining studies have estimated cancer rates between 0.018 and 0.028 annual cancer cases per million population. This results in a relative narrow absolute range when extrapolated to nationwide cancer cases of 4 to 7 per year. Of these four studies, three have even closer estimates, 0.018 to 0.02 annual cancer cases per million population. The slightly higher 35-County

TABLE B-16

ESTIMATED ANNUAL CANCER CASES FROM ETHYLENE OXIDE BY SOURCE CATEGORY

SOURCE CATEGORY	INDIVIDUAL STUDY						NATIONWIDE	
	NESHAP/ ATERIS	Thirty-five County	Five City	IEMP-Kanawha Valley	IEMP-Santa Clara	Southeast Chicago	RANGE[a]	POINT ESTIMATE[b]
Commercial Sterilization/ Hospitals	3.1-11.5[c] (0.013-0.048)		1.57 (0.099)		x	0.0043 (0.011)	2.6-24	3-4
ETO Production	1.2 (0.005)						1.2	1.2
Unspecified Sources		1.31 (0.028)	0.157 (0.01)		x	0.0029 (0.0073)	1.7-6.7	--
Chemical Mfg.			0.026 (0.0016)	0.35-0.84 (3.5-8.43)			0.7-1.2[d]	1
TOTALS								
MODELED	4.3-12.7 (0.018-0.053)	1.31 (0.028)	1.75 (0.11)	0.35-0.84 (3.5-8.43)	0.03 (0.02)	0.0071 (0.018)	4.5-26[e]	5-6

Footnotes to Table B-16.

NOTE: Numbers in parentheses are annual cancer cases per million population. For nationwide studies, annual cancer cases were divided by 240 million, unless otherwise noted. For studies with smaller geographic scopes, the annual cancer cases were divided by the study's population.

NOTE: An "x" in a column indicates that the source category was considered in the study, but a specific cancer risk for the source category was not indicated.

[a] The numbers in this column were calculated by taking the lowest and highest incidence rates for a source category and multiplying it by 240 (1986 U.S. population in millions). The total for this column is the summation of the low end of the range and the sum of the high end of the range.

[b] The numbers in this column present the results of the reduction analyses. In most instances, a point estimate of nationwide annual cancer incidence was derived for each pollutant/source category combination. In some instances, a point estimate could not be reasonably derived. For these instances, as narrow a range as possible of nationwide annual cancer incidence was estimated, and such ranges appear in this column. The text discusses how these point estimates and ranges were derived.

[c] Upper range is based upon original NESHAP study in which commercial sterilizers are identified as contributing 86 percent of total annual cancer cases. Low range is based on annual cancer cases reported in the ATERIS file.

[d] Does not include extrapolating incidence rate from IEMP-Kanawha Valley to nationwide estimate of annual cancer cases because of uncertainty as to type of facility or facilities emitting the ethylene oxide and lack of information on which to obtain a nationwide estimate. Range is created by adding the annual cancer cases estimated in the IEMP-Kanawha Valley to the nationwide cancer risk estimate obtained by extrapolating the 5-City study's incidence rate to the total U.S. population.

[e] Does not include "unspecified sources" source category of the 35-County, the 5-City, or the Southeast Chicago studies. See text for discussion.

cancer rate may be due to the selection of counties with known sources of ethylene oxide emissions (e.g., commercial sterilizers). If the higher estimate for commercial sterilizers from the NESHAP/ATERIS data base is used, then the range is approximately 4 to 13 cancer cases per year nationwide.

The 5-City study has a calculated cancer rate of 0.11 annual cancer cases per million population. One city has a cancer rate of 0.144 cancer cases per year per million population, with the other four cities having rates between 0.001 and 0.04. Without the one city, the cancer rate for the remaining four cities is calculated to be 0.022 cancer cases per year per million population. This estimate is much more in line with the other studies. The high cancer rate in the one city, which is also located in one of the counties in the 35-County study, appears to be attributable to an abundance of commercial sterilizers. Based on information in the NESHAP/ATERIS data base, this city has approximately 9 commercial sterilizers, whereas each of the other four cities have between 0 and 2 commercial sterilizers.

Point Estimate. Excluding the IEMP-Kanawha Valley study and based on the above considerations, a nationwide estimate based upon 0.02 annual cancer cases per million population appears to be a reasonable estimate. This results in an estimate of approximately 4 to 5 cancer cases per year. The sources covered in the IEMP-Kanawha Valley appear to be independent of the other source categories. Thus, the approximately 1 cancer case per year from that study can be added to the 4 to 5 cancer cases per year to result in 5 to 6 cancer cases per year.

Formaldehyde. Ten studies considered formaldehyde in their estimate of cancer risk from ambient air pollutants (see Table B-17). Numerous chemical manufacturing production processes and other point sources contribute to formaldehyde emissions. In addition, area sources, such as motor vehicles, contribute to formaldehyde emissions. Finally, a large portion of formaldehyde in the air is the result of secondary formation. This source of formaldehyde is not typically accounted for in modeling studies because there are no validated photochemical models to estimate secondary formaldehyde production from VOC and other precursors. Thus, assessments based on ambient monitoring data provide a more complete accounting of actual exposure to formaldehyde than from emission estimates alone.

Ambient Estimates. Average annual formaldehyde data used in the Ambient Air Quality study ranged from 1.1 to 5.0 $\mu g/m^3$ for individual locales. Estimates of cancer risk in the Ambient Air Quality study were made using an average urban concentration of 3.16 $\mu g/m^3$ and an average rural concentration of 1.50 $\mu g/m^3$. The South Coast study used a concentration of approximately 14.7 $\mu g/m^3$ to estimate cancer risk. In the 5-City study, a single representative annual average formaldehyde concentration was selected for each city, ranging from 3 $\mu g/m^3$ to 6.7 $\mu g/m^3$. In the Southeast Chicago Study, an ambient-measured concentration of 2.98 $\mu g/m^3$ was obtained at a single site. This concentration reflects 16 samples collected for 24 hours every 12 days from September 1987 to March 1988. However, the Southeast Chicago study notes that "the absence of data from the summer, when photochemical formation of formaldehyde is greatest, indicates that available data probably understate the annual average formaldehyde concentration."

TABLE B-17

ESTIMATED ANNUAL CANCER CASES FROM FORMALDEHYDE BY SOURCE

SOURCE CATEGORY	INDIVIDUAL STUDY						
	Ambient Air Quality	NESHAP/ ATERIS	Coal and Oil Combustion	Mobile Sources	Municipal Incinerators	TSDFs	Thirty-five County
Chemical Manufacturing		0.062^c (0.0003)					
Motor Vehicles				43^d-48^e (0.18-0.2)			9-10 (0.2)
Heating/ Combustion			0.01 (0.00004)				3.37 (0.07)
Municipal Combustors							
Municipal Waste Incinerators					0.009 (0.00004)		
TSDFs						0.31 (0.0013)	
Unspecified Sources		1.81 (0.0075)					2.93 (0.06)
Nonferrous Smelters							
Petroleum Refining							
Solvent Use							
Woodsmoke							
Secondary Formation							
TOTALS							
MODELED		0.062-1.81 (0.0003-0.0075)	0.01 (0.00004)	43^d-43^e (0.18-0.2)	0.009 (0.00004)	0.31 (0.0013)	13.0 (0.27)
AMBIENT	124 (0.52)						

TABLE B-17 -- concluded

ESTIMATED ANNUAL CANCER CASES FROM FORMALDEHYDE BY SOURCE

SOURCE CATEGORY	INDIVIDUAL STUDY			NATIONWIDE	
	Five City	Southeast Chicago	South Coast	RANGE[a]	POINT ESTIMATE[b]
Chemical Manufacturing	0.05 (0.003)			0.07-0.72	0.5
Motor Vehicles	4.17 (0.26)	0.0186 (0.047)		11.3-62	48
Heating/ Combustion	0.39 (0.025)	0.0032 (0.008)		0.01-16.8	0.01
Municipal Waste Combustors					
Municipal Incinerators				0.009	0.01
TSDFs		negligible		0.31	0.31
Unspecified Sources	1.43 (0.009)	0.0028 (0.008)		1.9-21.6	2-22
Nonferrous Smelters	0.16 (0.01)			2.4	2.4
Petroleum Refining	0.21 (0.013)			3.1	3.1
Solvent Use	0.0004 (0.00002)			0.005	0.005
Woodsmoke	0.23 (0.014)			3.4	3.4
Secondary Formation	10.1 (0.64)	0.174 (0.44)		106-154	106-154
TOTALS					
MODELED	16.73 (1.05)	0.024 (0.06)		23-110[f] 129-264[g]	60-80[f] 166-234[g]
AMBIENT		0.194 (0.494)	28.6 (2.62)	119-629	124

Footnotes to Table B-17.

NOTE: Numbers in parentheses are annual cancer cases per million population. For nationwide studies, annual cancer cases were divided by 240 million, unless otherwise noted. For studies with smaller geographic scopes, the annual cancer cases were divided by the study's population.

[a] The numbers in this column were calculated by taking the lowest and highest incidence rates for a source category and multiplying it by 240 (1986 U.S. population in millions). The total for this column is the summation of the low end of the range and the sum of the high end of the range.

[b] The numbers in this column present the results of the reduction analyses. In most instances, a point estimate of nationwide annual cancer incidence was derived for each pollutant/source category combination. In some instances, a point estimate could not be reasonably derived. For these instances, as narrow a range as possible of nationwide annual cancer incidence was estimated, and such ranges appear in this column. The text discusses how these point estimates and ranges were derived.

[c] Source categories are: phenolic formaldehyde resins; urea formaldehyde; formaldehyde production; melamine formaldehyde; 1,4-butanediol; 4,4-methylenedianol; hexamethlenetetramin; pentaerylthiotol; phthalic anhydride; polyacetal resin, and trimethylolpropane.

[d] Assumes 35 percent of ambient concentrations are attributable to motor vehicles. Calculated by multiplying risk from Ambient Air Quality study by 35 percent.

[e] Based on modeling of direct formaldehyde emissions.

[f] Excludes cancer risk from "secondary formation" source category.

[g] Includes cancer risk from "secondary formation" source category.

Of these four studies, the Ambient Air Quality study contains the most complete set of ambient-measured concentration data. Some of the earlier data collected apparently were sampled using older sampling techniques that are now known to bias the data, overestimating ambient concentrations. Recently collected data, which are used in the Ambient Air Quality study, show that ambient-measured concentrations may be approximately one-half to one-third of the average concentrations measured previously. Based upon the new set of formaldehyde concentration data, the Ambient Air Quality study estimates 124 cancer cases per year. The techniques used to obtain the samples and the concentrations reported in the South Coast study were not identified in the report. The data used in the South Coast study, however, came from samples collected between 1980 and 1984. This suggests that some of these data may have been collected using sampling techniques that are now known to overestimate formaldehyde concentrations. The Ambient Air Quality study's estimate of 124 cancer cases per year is selected as the best nationwide estimate of risk from among the studies that based their risk estimates on ambient-measured concentrations.

Modeled Estimates. As seen in Table B-17, total nationwide cancer risk based on the modeled estimates is calculated to be between 23 and 110 cancer cases per year, with a best estimate range of 60 to 80 cancer cases per year. Two studies, the 5-City study and the Southeast Chicago study, calculated the difference between the cancer risks estimated based on selected or measured concentrations and the cancer risks estimated based on the modeled concentrations, and assigned the difference to a "secondary formation" category. When the risk estimates for "secondary formation" are included, the total risk based on modeled emissions range from 166 to 234 cancer cases per year.

Of the individual source categories, the largest discrepancy occurs with estimates of risk from primary (direct) formaldehyde emissions from motor vehicles. Three of the four studies estimate a cancer rate of approximately 0.2 to 0.26 cancer cases per year per million population. The Southeast Chicago study estimate is about one-fifth (0.047 cancer cases per year per million population) of this cancer rate. Part of this difference appears to be due to the particular vehicle mix and/or average speed in the Southeast Chicago area that led to lower average hydrocarbon emissions and to lower formaldehyde emissions. It has been estimated based on information in the Southeast Chicago study that a comparably based formaldehyde emission factor of between 0.011 and 0.033 g/mile was used, being approximately 25 to 75 percent lower than the emission factors used in the Mobile Source study. Adjusting the Southeast Chicago cancer rate for this difference in emission factors results in an adjusted cancer rate between 0.06 and 0.19 cancer cases per year per million population. Different models used in the two studies may explain the remaining differences.

Point Estimate. As noted above, ambient-measured data can directly account for formaldehyde that is the result of secondary formation, whereas models can not. Thus, risk estimates based on ambient-measured concentrations are to be preferred. Of the studies that estimated risk using ambient-measured concentrations, the Ambient Air Quality study had the broadest geographic data base, which is preferred for nationwide estimates. (The three individual studies that used ambient-measured concentrations more reasonably show the city-to-city variation that may be associated with formaldehyde.) Based on the recently obtained data in the Ambient Air Quality study, the estimate of nationwide cancer risk is estimated to be 124 cancer cases per year due to exposure to formaldehyde.

Gasoline Vapor. Eight studies examined risk from exposure to gasoline vapors (see Table B-18). Sources of gasoline vapors were identified as vapor displacement due to the refueling of motor vehicles, the transfer of gasoline at bulk terminals, bulk plants, and refineries, and TSDFs. One study, the Southeast Chicago study, also identified evaporative gasoline vapors loss from motor vehicles. All of the risk estimates for gasoline vapors are based on modeled ambient concentrations.

Modeled Estimates. The primary study on gasoline vapors is the Gasoline Marketing study. Table B-19 shows the breakdown by sources within the gasoline marketing source category as estimated in the Gasoline Marketing study. Several of the studies (e.g., the Mobile Source study) appear to have incorporated the results of the Gasoline Marketing study. As seen in Table B-19, cancer risks are shown for both total gas vapors and for the "C_6 and higher" fraction of gas vapors. Some evidence suggests that it is the C_6 and higher fraction of gas vapors that is the carcinogenic portion. At this time, it is EPA's policy to report both numbers with equal weight until further studies suggest whether risks based on total gas vapors or on the C_6+ fraction are preferred.

As noted above, the Southeast Chicago study estimated risk from evaporative gasoline vapor loss from motor vehicles. This risk was estimated, in part, by treating evaporative emissions as equivalent to gasoline vapors and estimated the risk using the cancer risk factor for gasoline vapor. The Office of Mobile Sources, however, states that "the composition of totally vaporized gasoline is markedly different from evaporative emissions" and that "the majority of evaporative emissions are C_6 and lower." Thus, the estimate provided in the Southeast Chicago

TABLE B-18

ESTIMATED ANNUAL CANCER RISK FROM GASOLINE VAPOR BY SOURCE CATEGORY

SOURCE CATEGORY	INDIVIDUAL STUDY								NATIONWIDE	
	Gasoline Marketing	Mobile Sources	TSDFs	Thirty-five County	Five City	IEMP-Philadelphia	IEMP-Santa Clara	Southeast Chicago	RANGE[a]	POINT ESTIMATE[b]
Gasoline Marketing	17-68 (0.07-0.28)	36 (0.15)		6.16 (0.13)	0.76 (0.05)	0.044 (0.027)		0.013 (0.033)	6-68	68
Motor Vehicles								0.037 (0.095)	23	--c
TSDFs			0.016 (0.00007)						0.016	0.016
Refineries						0.055 (0.033)			8	<8
TOTALS										
Total gas vapors	68 (0.28)	36 (0.15)	0.016 (0.00007)	6.16 (0.13)	0.76 (0.05)	0.099 (0.06)	0.09 (0.07)	0.066 (0.17)	37-99	76
C6+	17 (0.07)								8.5-23	19

NOTE: Numbers in parentheses are annual cancer cases per million population. For nationwide studies, annual cancer cases were divided by 240 million, unless otherwise noted. For studies with smaller geographic scopes, the annual cancer cases were divided by the study's population.

[a] The numbers in this column were calculated by taking the lowest and highest incidence rates for a source category and multiplying it by 240 (1986 U.S. population in millions). The total for this column is the summation of the low end of the range and the sum of the high end of the range.

[b] The numbers in this column present the results of the reduction analyses. In most instances, a point estimate of nationwide annual cancer incidence was derived for each pollutant/source category combination. In some instances, a point estimate could not be reasonably derived. For these instances, as narrow a range as possible of nationwide annual cancer incidence was estimated, and such ranges appear in this column. The text discusses how these point estimates and ranges were derived.

[c] Due to the differences in composition of evaporative emissions and gasoline vapor, it was felt that at this time insufficient information was available to provide a point estimate of cancer incidence from evaporative emissions from motor vehicles. See text for additional discussion.

TABLE B-19

ESTIMATED ANNUAL CANCER CASES FROM GASOLINE MARKETING

Facility Category	Average Annual Incidence	
	Total Gas Vapor	C_6 and Higher
Bulk Terminals	3.5	0.9
Bulk Plants	1.4	0.4
Service Stations		
Community Exposure	13	3.3
Self-service	33	8.3
Occupational	17	4.3
TOTAL	68	17

study is likely to be a very conservative (i.e., overestimate) estimate of risk from evaporative emissions.

Point Estimate. Since the risks from motor vehicle evaporation and petroleum refineries are exclusive from the gasoline marketing source category, the cancer risks can be summed from each. However, due to the differences in composition of evaporative emissions from gasoline vapor, it was felt that, at this time, insufficient information was available to include an estimate of cancer risk from evaporative emissions as part of the best estimate. Thus, based on total gas vapors, a nationwide cancer risk of approximately 76 cases per year is calculated. Assuming the risk comes only from the C_6+ fraction, which is approximately 25 percent of totally vaporized gas, nationwide cancer cases are estimated to be approximately 19 per year. Extrapolation of the refinery incidence rate from the IEMP-Philadelphia study to nationwide incidence is uncertain due to the point source nature of petroleum refineries. The effect of this extrapolation, however, is likely to have a smaller effect on total cancer risk from gas vapors than the total vapor vs. C_6+ fraction question. Thus, a range of 19 to 76 cancer cases per year nationwide was selected as the estimate of nationwide annual cancer incidence due to exposure to gasoline vapors.

Methylene chloride. Eleven studies included methylene chloride as a pollutant of concern (see Table B-20). Two of the studies (the IEMP-Kanawha Valley and the South Coast studies) had estimated annual incidences per million population that would result in 10 or more cancer cases per year if extrapolated to the total U.S. population. The ambient concentrations used to calculate the cancer risk in these two areas reflect geographic variation as seen in the ambient monitoring data used in the Ambient Air Quality study. The IEMP-Kanawha Valley study reported ambient concentrations ranging from 3.1 to 20.8 $\mu g/m^3$ and the South Coast study from 7.7 to 17.3 $\mu g/m^3$. The Ambient Air Quality study's data base showed ambient concentrations ranging from approximately 0.5 to 10.0 $\mu g/m^3$. Thus, it is not reasonable to use either of these two cancer rates to estimate nationwide cancer cases.

The Ambient Air Quality study's results are based on the largest data base. Based on a population weighted urban concentration of approximately 4.0 $\mu g/m^3$ and a nonurban concentration of approximately 0.2 $\mu g/m^3$, the Ambient Air Quality study estimated approximately 5 cancer cases per year, or a cancer rate of 0.02 cancer cases per year per million population. This cancer rate is essentially the same as that obtained by summing individual source categories in the 35-County and the 5-City studies. Total nationwide instances, in either case, are approximately 5 cancer cases per year.

TABLE B-20

ESTIMATED ANNUAL CANCER CASES FROM METHYLENE CHLORIDE BY SOURCE CATEGORY

SOURCE CATEGORY	INDIVIDUAL STUDY						
	Ambient Air Quality	NESHAP/ATERIS	POTWs	TSDFs	Thirty-five County	Five City	IEMP-Kanawha Valley
Pesticide Production		0.0045 (0.00002)					
Pharmaceutical Mfg.		0.04 (0.00017)					
Paint and Other Stripping		0.22 (0.0007)					
Chemical Users and Producers		0.14 (0.00059)					0.0012-0.003 (0.012-0.03)
POTWs			0.03 (0.0001)				
TSDFs				0.07 (0.0003)			
Unspecified					0.037 (0.00078)		
Solvent Usage					0.85 (0.018)	0.33 (0.02)	0.0012 (0.012)
Aerosol							
Area							
TOTALS							
Modeled		0.4 (0.0017)	0.03 (0.0001)	0.07 (0.0003)	0.89 (0.019)	0.33 (0.02)	0.0024-0.0042 (0.024-0.042)
Ambient	5 (0.02)						

TABLE B-20 -- concluded

ESTIMATED ANNUAL CANCER CASES FROM METHYLENE CHLORIDE BY SOURCE CATEGORY

	INDIVIDUAL STUDY				NATIONWIDE	
SOURCE CATEGORY	IEMP-Philadelphia	IEMP-Santa Clara	Southeast Chicago	South Coast	RANGE[a]	POINT ESTIMATE[b]
Pesticide Production					0.0045	0.0045
Pharmaceutical Mfg.	0.0016 (0.001)				0.04-0.24	0.04-0.24
Paint and Other Stripping			x		0.22	0.22
Chemical Users and Producers					0.14[c]	0.14
POTWs	negligible		negligible		0-0.03	0.03
TSDFs			negligible		0.07	0.07
Unspecified	0.0013 (0.00076)	x	0.00057 (0.00145)	x	0-0.35	--
Solvent Usage	0.0013 (0.00076)	x			2.9-4.8	2.9-4.8
Aerosol			x		--	--
Area			0.0014 (0.0036)	x	0.9	--
TOTALS						
Modeled	0.0066 (0.004)	0.0011 (0.0008)	0.002 (0.005)	0.386 (0.035)	4.3-6.8	3-5.5
Ambient				0.92 (0.084)	5-20.5	5

Footnotes to Table B-20.

NOTE: Numbers in parentheses are annual cancer cases per million population. For nationwide studies, annual cancer cases were divided by 240 million, unless otherwise noted. For studies with smaller geographic scopes, the annual cancer cases were divided by the study's population.

NOTE: An "x" in a column indicates that the source category was considered in the study, but a specific cancer risk for the source category was not indicated.

[a] The numbers in this column were calculated by taking the lowest and highest incidence rates for a source category and multiplying it by 240 (1986 U.S. population in millions). The total for this column is the summation of the low end of the range and the sum of the high end of the range.

[b] The numbers in this column present the results of the reduction analyses. In most instances, a point estimate of nationwide annual cancer incidence was derived for each pollutant/source category combination. In some instances, a point estimate could not be reasonably derived. For these instances, as narrow a range as possible of nationwide annual cancer incidence was estimated, and such ranges appear in this column. The text discusses how these point estimates and ranges were derived.

[c] Does not include extrapolating the incidence rate from the IEMP-Kanawha Valley study to nationwide cancer risk estimate because of the uncertainty as to the type of facilities being modeled.

Perchloroethylene. Fifteen studies included perchloroethylene as a pollutant of concern (see Tables B-21 and B-22). Several of the studies examined both ambient measured and model predicted concentrations. Within a study, ambient measured concentrations were in general higher than those predicted by the models, but in general were in reasonably good agreement.

Based on the modeled estimates (see Table B-21) available for specific source categories, nationwide cancer cases are estimated to be between approximately 4 and 11 per year. Based on the ambient-measured data estimates (see Table B-22), nationwide incidences due to perchloroethylene appear to fall between approximately 6 and 13 cancer cases per year. Although one of the studies (the South Coast study) has a cancer rate that would extrapolate to a somewhat higher nationwide incidence of 10 to 13 cancer cases per year, the cancer rate is due to the geographic variability of perchloroethylene and it would not be reasonable to extrapolate to the nationwide estimate.

Point Estimate. Risk from perchloroethylene seems to be highly variable with geographic location, though overall risk appears to be relatively small. The scope of the Ambient Air Quality study and its data account for this geographic variability. Therefore, the result from the Ambient Air Quality study, 6 cancer cases per year, was selected as the estimate of nationwide annual cancer incidence due to exposure to perchloroethylene.

TABLE B-21

ESTIMATED ANNUAL CANCER CASES FROM PERCHLOROETHYLENE BY SOURCE CATEGORY - MODELED CONCENTRATIONS

SOURCE CATEGORY	INDIVIDUAL STUDY							
	NESHAP/ ATERIS	Drinking Water Aerators	POTWs	Sewage Sludge Incinerators	TSDFs	Waste Oil Combustors	Thirty-five County	Five City[a]
Miscellaneous Chemical Mfg.	0.0026-0.99 (0.00001-0.004)						0.10 (0.002)	0.001 (0.00006)
TSDFs					0.088 (0.0004)			
Sewage Sludge Incinerators				0.10 (0.0004)				
POTWs			0.07 (0.0003)				0.03 (0.0006)	
Solvent Usage/ Degreasing							1.4 (0.03)	0.20 (0.013)
Waste Oil Burning						negligible	negligible	
Dry Cleaning								0.20 (0.013)
Industrial Solvent Coatings								
Drinking Water Aerators		<0.0047 (0.00002)						
TOTALS Modeled	0.0026-0.99 0.00001-0.004)	<0.0047 (0.00002)	0.07 (0.0003)	0.10 (0.0004)	0.088 (0.0004)	negligible	1.53 (0.032)	0.40 (0.025)

TABLE B-21 -- concluded

ESTIMATED ANNUAL CANCER CASES FROM PERCHLOROETHYLENE BY SOURCE CATEGORY - MODELED CONCENTRATIONS

SOURCE CATEGORY	INDIVIDUAL STUDY					NATIONWIDE	
	IEMP-Kanawha Valley	IEMP-Philadelphia	IEMP-Santa Clara	Southeast Chicago	South Coast	RANGE[b]	POINT ESTIMATE[c]
Miscellaneous Chemical Mfg.		negligible	x	0.00057 (0.00145)		0.003-0.99	<1
TSDFs				negligible		0.088	0.088
Sewage Sludge Incinerators						0.10	0.1
POTWs		0.0009 (0.0005)	x	negligible		0.072-0.14	0.1
Solvent Usage/ Degreasing	0.0026 (0.026)	0.003 (0.002)	x	x		0.48-7.2	3-7
Waste Oil Burning	negligible					0	0
Dry Cleaning		0.022 (0.013)	x	x		3.12	3.12
Industrial Solvent Coatings			x			--	--
Drinking Water Aerators						<0.0047	<0.0047
TOTALS							
Modeled	0.0026 (0.026)	0.026 (0.016)	0.036 (0.026)	0.002 (0.005)	0.518 (0.048)	3.8-11.5[d]	7-11

Footnotes to Table B-21.

NOTE: Numbers in parentheses are annual cancer cases per million population. For nationwide studies, annual cancer cases were divided by 240 million, unless otherwise noted. For studies with smaller geographic scopes, the annual cancer cases were divided by the study's population.

NOTE: An "x" in a column indicates that the source category was considered in the study, but a specific cancer risk for the source category was not indicated.

[a] Negligible sources: nonferrous smelters and chemical manufacturing.

[b] The numbers in this column present the results of the reduction analyses. In most instances, a point estimate of nationwide annual cancer incidence was derived for each pollutant/source category combination. In some instances, a point estimate could not be reasonably derived. For these instances, as narrow a range as possible of nationwide annual cancer incidence was estimated, and such ranges appear in this column. The text discusses how these point estimates and ranges were derived.

[c] The numbers in this column reflect the results of the analysis as to what single estimate or range of estimate better reflects the most likely estimate of risk. The text discusses how these single estimates or ranges were selected.

[d] Based only on the quantitative estimates identified for specific source categories. If the incidence rates from the IEMP-Santa Clara, Southeast Chicago, and the South Coast studies were applied to the U.S. population (240 million), a range of nationwide cancer cases per year from 1.2 to 11.5 is calculated.

TABLE B-22

MEASURED AMBIENT CONCENTRATIONS OF PERCHLOROETHYLENE

STUDY	CONCENTRATION ($\mu g/m^3$)	Cancer Cases by Study Per Year	Cancer Cases by Study Per Million Population	Nationwide Cancer Cases Per Year
Ambient Air Quality				
Range	0.33-17.0	6	0.025	6
Urban	3.83			
Rural	0.3			
South Coast	6.8	0.59	0.054	13
IEMP-Kanawha Valley	1.0-3.4	--	--	--
IEMP-Baltimore				
Range	1.5-9.3	0.06	0.038	9
Average	5.51			
IEMP-Philadelphia	4.7	0.06	0.039	9
Totals				
Range				6-13
Point Estimate				6

PIC. "Products of Incomplete Combustion" (PIC) is a term used to refer to a large number of organic particulate compounds that result from incomplete combustion, such as may occur from gasoline- and diesel-fueled motor vehicles. These organic particulate compounds consist primarily of polynuclear organics, or, synonymously, polycyclic organic matter (POM). POMs would therefore be considered a subset of the compounds termed PIC.

Polycyclic organic matter, in turn, is a generic term that covers hundreds of chemical substances that contain two or more ring structures. Compounds covered by the term POM include: (1) compounds composed only of carbon and hydrogen, which are known as polycyclic aromatic hydrocarbons (PAHs); (2) compounds with a ring nitrogen (aza and imino arenes); (3) oxygenated species; and (4) nitrated and chlorinated POM, including dioxins and pesticides such as aldrin and DDT.

Polycyclic aromatic hydrocarbons (PAH's) can be divided into three compound categories: (1) naphthalene; (2) the anthracene groups; and (3) the benzo(a)pyrene (BaP) group. The individual constituents of the last group include BaP, acenaphthylene, benz(a)anthrancene, benzo(k)fluoranthene, benz(g,h,i)perylene, and indeno(1,2,3-c,d)pyrene.

Risk Estimation. Twelve studies include risk estimates for PIC. A total of four different risk estimation methodologies were used. These studies and the risk estimation methodologies used in each study are shown in Table B-23. The most frequently used methodology assumed that all of the risk from PIC can be adequately represented by using BaP emissions as a surrogate. This methodology uses measured or modeled BaP emission concentrations and applies either (1) the BaP unit risk factor or (2) the PIC unit risk factor to those concentrations to calculate

TABLE B-23

VARIOUS ESTIMATION METHODOLOGIES USED FOR PIC

METHODOLOGY	Ambient Air Quality	Coal and Oil Combustion	Mobile Sources	Municipal Waste Combustors	TSDFs	Thirty-five County	Five City	IEMP-Kanawha Valley	IEMP-Santa Clara	Southeast Chicago
BaP emission factor and BaP unit risk factor	X	X	X			X		X	X	
BaP emission factor and PIC unit risk factor	X		X			X	X[a]			
PIC/POM/BaP component emission factors and unit risk factors or PIC/POM/BaP unspeciated emission factor and comparative potency unit risk factor			X		X	X	X			
PAH/POM emission factor and BaP unit risk factor				X					X	X

[a] Used for minor sources of POM where comparative potency factors were not available.

risk. (Note: The 35-County study treated these two approaches as non-duplicative and summed their results to give an estimate of total risk from all PIC compounds.) For example, suppose an ambient BaP concentration of 1 $\mu g/m^3$ is measured. A population of 100,000 people is exposed to this concentration for 70 years. Applying the unit risk factor for BaP of $1.7x10^{-3}$ $(\mu g/m^3)^{-1}$ yields an estimated 170 cancer cases over 70 years, or approximately 2.4 cancer cases per year. This methodology assumes that all of the risk from PIC is attributable to BaP. In other words, none of the other components have any cancer risk associated with them. Suppose instead the PIC unit risk factor of $4.2x10^{-1}$ (from the Six-Month Study) was applied to this measured ambient concentration. Estimated cancer cases from PIC in this example would be 42,000 over 70 years, or 600 cancer cases per year. The method used to calculate the PIC unit risk factor reported in the Six-Month Study was unusual and any risk estimate based on its use should be treated as a very preliminary estimate.

A second variation involving BaP was to use specific PAH/POM emission factors specific to a particular source category to estimate concentration levels of PIC and then apply the BaP unit risk factor to estimate risk. This methodology, which is separate and distinct from the first two identified, assumes that the average unit risk of all components that make up the modeled concentration is the same as the unit risk factor for BaP or that each component has the same risk value.

Another methodology uses individual PIC component emission factors specific to a particular source category to estimate the concentrations of the individual components within the PIC mixture and applies to those concentrations the corresponding unit risk factors for those components.

This technique allows for variation in the overall unit risk factor that is estimated for specific source categories.

A similar methodology is known as the comparative potency factor approach. This approach involves using an emission rate for particle-associated organics (as an unspeciated mixture) and a unit risk factor for these organics as an unspeciated mixture. This approach has been used, for example, in estimating risk from diesel emissions. The unit risk factor for a suspect human carcinogen (e.g., diesel emissions) for which there are no epidemiological cancer data is estimated by comparison to a known human carcinogen (e.g., coke oven emissions); the risk associated with the known human carcinogen is multiplied by bioassay potency of the suspect human carcinogen divided by the bioassay potency of the known human carcinogen. (A variation on this methodology is to use particulate emission factors and comparative potency unit risk factors adjusted to reflect the particle-associated organic fraction.)

Table B-24 summarizes the risk estimates from the ten studies, broken down by source category. Two of the ten studies estimated risk based on ambient measurements; the others based their risk estimates on modeled concentrations.

Ambient Estimates. The two studies that used ambient measurements were the IEMP-Santa Clara study and the Ambient Air Quality study. The IEMP-Santa Clara study estimated cancer risk by scaling other national ambient concentration data for PAH's from similar urban areas to estimate PAH concentrations. Using EPA's unit risk factor of 1.7 x 10^{-3} $(\mu g/m^3)^{-1}$ for BaP, cancer rates between 0.004 and 0.49 annual cancer cases per million population are calculated. These rates correspond to a PAH (BaP group) concentration of 0.00016 $\mu g/m^3$ to 0.02 $\mu g/m^3$. These

TABLE B-24

ESTIMATED ANNUAL CANCER CASES FROM PIC BY SOURCE CATEGORY

SOURCE CATEGORY	INDIVIDUAL STUDY								
	Ambient Air Quality	Coal and Oil Combustion	Hazardous Waste Combustors	Mobile Sources	Municipal Waste Combustors	TSDFs	Thirty-five County	Five City	IEMP-Kanawha Valley
Coal and Oil Combustion		1.1 (0.0046)					x	0.029 (0.0018)	
Municipal Waste Combustors					0.01-0.6 (0.00004-0.003)		x		
Motor Vehicles									
- Gasoline				1.3^{c}-122^{d} (0.51)				7.9 (0.5)	0.0014^{c} (0.014)
				163-176^{e} (0.68-0.73)					
- Diesel				178-860 (0.74-3.58)				11.2 (0.71)	
Subtotal				300-982 (1.25-4.1)			0.41^{c}-102^{d} (0.01-2.16)	19.2 (1.21)	0.0014 (0.014)
				341-1036 (1.42-4.32)			55.6^{e} (1.18)		
Waste Oil Burning							0^{e}-0.005^{d} (0-0.0001)		negligible
Heating/ Woodstoves							0.38^{c}-48^{d} (0.013-1.01)	4.7 (0.3)	0.0018 (0.018)
TSDFs						0.025 (0.0001)			
Hazardous Waste Combustors			0.014-0.06 (0.00006-0.002)						

TABLE B-24 -- continued

ESTIMATED ANNUAL CANCER CASES FROM PIC BY SOURCE CATEGORY

SOURCE CATEGORY	INDIVIDUAL STUDY								
	Ambient Air Quality	Coal and Oil Combustion	Hazardous Waste Combustors	Mobile Sources	Municipal Waste Combustors	TSDFs	Thirty-five County	Five City	IEMP-Kanawha Valley
Iron and Steel								0.34 (0.022)	
Sewage Sludge Incinerators									
Other[f]							0.15 (0.38)	0.89 (0.056)	
TOTALS									
MODELED		1.1 (0.0046)	0.014-0.06 (0.0006-0.002)	301-1,036 (1.25-4.32)	0.01-0.6 (0.00004-0.003)	0.025 (0.0001)	67-150 (1.41-3.17)	25.1 (1.58)	0.0032 (0.032)
AMBIENT	4[g]-876[h] (0.017-3.65)								

TABLE B-24 -- concluded

ESTIMATED ANNUAL CANCER CASES FROM PIC BY SOURCE CATEGORY

SOURCE CATEGORY	INDIVIDUAL STUDY			NATIONWIDE	
	IEMP-Santa Clara	Southeast Chicago	Sewage Sludge Incinerators	RANGE[a]	POINT ESTIMATE[b]
Coal and Oil Combustion				0.43-1.5	0.43
Municipal Waste Combustors				0.01-0.6	0.01-0.6
Motor Vehicles					
- Gasoline				3.4-166	--
				163-176	168
- Diesel				178-860	178-860
Subtotal		0.053 (0.134)			346-1,028
Waste Oil Burning				0-0.025	<0.025
Heating/ Woodstoves		0.114 (0.29)		55-242	72
TSDFs				0.025	0.025
Hazardous Waste Combustors				0.014-0.06	0.014-0.06

TABLE B-24 -- concluded

ESTIMATED ANNUAL CANCER CASES FROM PIC BY SOURCE CATEGORY

SOURCE CATEGORY	INDIVIDUAL STUDY			NATIONWIDE			
	IEMP-Santa Clara	Southeast Chicago	Sewage Sludge Incinerators			RANGE[a]	POINT ESTIMATE[b]
Iron and Steel						0.34-5[i]	<5
Sewage Sludge Incinerators			1.52 (0.0063)			1.52	1.5
Other						13-91	13
TOTALS							
MODELED		0.167 (0.43)	1.52 (0.0063)				
				BaP URF[j] and EF[k] plus PIC URF and BaP EF	Point Sources	334	--
					Motor Vehicles	296-1026	--
					Total	630-1360	--
				POM EF and POM or Comparative Potency Unit Risk Factor	Stationary	58-93	92
					Motor Vehicles	341-1036	346-1,028
					Total	396-1125	438-1,120
AMBIENT	0.005[g]-0.68[h] (0.004-0.49)					1-876	4-876

Footnotes to Table B-24.

NOTE: Numbers in parentheses are annual cancer cases per million population. For nationwide studies, annual cancer cases were divided by 240 million, unless otherwise noted. For studies with smaller geographic scopes, the annual cancer cases were divided by the study's population.

NOTE: An "x" in a column indicates that the source category was considered in the study, but a specific cancer risk for the source category was not indicated.

[a] The numbers in this column were calculated by taking the lowest and highest incidence rates for a source category and multiplying it by 240 (1986 U.S. population in millions). The total for this column is the summation of the low end of the range and the sum of the high end of the range.

[b] The numbers in this column present the results of the reduction analyses. In most instances, a point estimate of nationwide annual cancer incidence was derived for each pollutant/source category combination. In some instances, a point estimate could not be reasonably derived. For these instances, as narrow a range as possible of nationwide annual cancer incidence was estimated, and such ranges appear in this column. The text discusses how these point estimates and ranges were derived.

[c] Based on using BaP emission factor and unit risk factor. For Mobile Source study only, the cancer rate was calculated based on an urban population only.

[d] Based on using BaP emission factor and PIC unit risk factor of 4.2×10^{-1} $(\mu g/m^3)^{-1}$. For Mobile Source study only, the cancer rate was calculated based on an urban population only.

[e] Based on using PIC/POM/BaP component emission factors and unit risk factors.

[f] Industrial point sources; not specified.

[g] Based on applying BaP unit risk factor to BaP concentration.

[h] Based on applying PIC unit factor of 4.2×10^{-1} $(\mu g/m^3)^{-1}$ to BaP concentration.

[i] The lower end of the range (0.34 cancer cases per year) is created by assuming the 5-City study identifies all cancer cases attributed to PIC emissions from iron and steel mills. The upper end of the range (5 cancer cases per year) is created by assuming total nationwide cancer cases is equal to the cancer rate (0.022 cancer cases per year per million population) times the total U.S. population (240 million).

[j] URF = unit risk factor.

[k] EF = emission factor.

estimates were included in the IEMP-Santa Clara study to provide at least a rough estimate of cancer risk rather than ignore this pollutant altogether.

The Ambient Air Quality study estimated risk from PIC based upon 1986 and 1987 ambient BaP concentrations. These data were used because the 1982 through 1985 data were found to have a positive bias because of some unknown contamination. The 1986 and 1987 data are higher than the 1977 through 1980 data, but are significantly lower than the 1981 and 1982 data. The 1985 Ambient Air Quality study on BaP and PIC used the 1977-1982 period. (Since the IEMP-Santa Clara report was published in 1986, it is possible that at least some of the ambient data used in that study came from 1977-1982 period.) Using the BaP concentration (approximately 0.0006 $\mu g/m^3$) as an estimate for PIC emissions and then applying the Six Month Study's unit risk factor for PIC, 876 total annual cancer cases due to PIC were calculated. Assuming all of the cancer risk from PIC is due to BaP, the Ambient Air Quality Study estimated 4 cancer cases per year nationwide.

Of the two ambient-based estimates, the Ambient Air Quality study was selected as the better study from which to estimate nationwide risk than the Santa Clara study. This selection was based on consideration of the Ambient Air Quality Study's broader scope and use of more recent and, presumably, better ambient data. In addition, applying the IEMP-Santa Clara cancer rate to the national population would not be appropriate as the estimated ambient concentrations were calculated based on emission sources specific to Santa Clara. Based on the two methodologies used in the Ambient Air Quality study, a range of 4 to 876 cancer cases per year due to PIC is estimated.

Modeled Estimates. The other ten studies calculated ambient concentrations using models. Nine specific source categories and one "unspecified" source category were examined in these eight studies. Of the nine specific source categories, the most important contributor to cancer incidence is motor vehicles. Woodsmoke/woodstoves as part of the "heating/woodstove" source category are the second largest contributor. The other seven source categories appear to be relatively insignificant, totalling less than 8 cancer cases per year.

As shown in Table B-23, these studies used a variety of methods for estimating risk. In selecting estimates of cancer incidences per year per million population with which nationwide estimates of cancer incidence would be made, the cancer rates derived from unit risk factors based on the carcinogenicity of the entire PIC mixture were favored over those cancer rates derived from either assuming the entire cancer risk from PIC is attributable to BaP or using the Six-Month Study's unit risk factor for PIC. This was done because it was felt that the unit risk factors estimated for the PIC mixtures are an improvement over the other two approaches. In any event, the reader is reminded that the unit risk factors for specific PIC mixtures have not received the same level of scrutiny as for other pollutants and that all cancer risk estimates for PIC remain highly uncertain. The following paragraphs discuss the source categories and their estimated risk from PIC.

As noted above, motor vehicles appear to be the most important of the nine source categories associated with PIC. Five of the ten studies estimated risk from motor vehicles. Table B-25 summarizes the unit risk factors, annual cancer cases, and annual cancer cases per million population for this source category in the five studies. The 5-City study uses emission factor data provided by EPA's Office of Mobile

TABLE B-25

ESTIMATED ANNUAL CANCER CASES FROM PIC FROM MOTOR VEHICLES

STUDY	Pollutant Emission Factor	Unit Risk Factor	Annual Cancer Cases			Annual Cancer Cases Per Million Population
			Gasoline	Diesel	Total	
35-County	POM	Gasoline: 5.4E-04 Diesel: 6.6E-06	--	--	56	1.18
	BaP	BaP: 3.3E-03	--	--	0.8	0.02
	BaP	PIC: 4.2E-01			102	2.16
Mobile Sources	BaP	BaP: 3.3E-03	1.3	--	1.3	0.007[a]
	BaP	PIC: 4.2E-01	122	--	122	0.68[a]
	Particle associated organics	Gasoline: 2.5E-04	163-176	--	163-176	0.68-0.73[b]
		Diesel: 2.0E-05 to 10E-05	--	178-860	178-860	0.74-3.58[b]
					341-1,036	1.42-4.32
5-City	Particle associated organics	Gasoline: 1.2E-04 7.9E-04	7.9	--	7.9	0.5
		Diesel: 3.0E-05	--	11.3	11.3	0.71
					19.2	1.2
Southeast Chicago	POM	BaP: 1.7E-03	0.053	--	0.053	0.134
IEMP-Kanawha Valley	BaP	BaP: 3.3E-03	0.0028	--	0.0028	0.028

[a] Based on urban population only (180 million), as reported in the Mobile Source study.

[b] Based on urban (180 million) and rural (60 million) populationS, as reported in the Mobile Source study.

Sources, which were used in the Mobile Source study. The Mobile Source study uses more recent PIC emission factors than used in the 35-County study. However, due to different unit risk factors for gasoline and diesel particulates, the 35-County and Mobile Source studies result in nearly identical estimates of cancer incidences per year per million urban population. In the Mobile Source study, the estimates for cancer risk from organics associated with gasoline particulates using BaP emissions and the 1985 Six-Month Study's PIC unit risk factor results in an urban cancer rate of approximately 0.68 cancer cases per year per million urban population, which is essentially identical to the urban cancer rate calculated using emission factors for gasoline particle-associated organics and a unit risk factor for these organics. This, in turn, is the same as that found in the 35-County study, where the only difference is in the emission rate.

The IEMP-Kanawha Valley and the Southeast Chicago study use data more specific to their locales. In the case of the IEMP-Kanawha Valley, information of the emission rate used to estimate BaP emissions was not available. The Southeast Chicago study used an emission factor for POM, which is approximately 55 times larger than the BaP emission factor used in the Mobile Source Study. When the same emission factor and unit risk factor are used, the resulting annual cancer incidence per million population between the two studies are the same.

In summary, the results from the Mobile Source study seem to be the best national estimate for risk from motor vehicles. The differences between studies seem to lie mainly in the assumptions concerning emission factors and unit risk factors, although different models were used. Among the estimates of risk reported in the Mobile Sources study, the best estimate of PIC risk from motor vehicles was selected as that estimated using the unit risk factors estimated specifically for diesel particulates and gasoline particulates. For organics associated with gasoline particulates from motor vehicles, an estimate of 163 to 176 annual cancer cases is selected. For diesel particulate, the range of 178 to 860 is selected, because of the inability at this time to select a more likely unit risk factor from the range reported in the Mobile Source study.

Woodsmoke/woodstoves were estimated to be the second largest potential source of risk from PIC. Estimated cancer rates ranged from 0.018 to 1.01 cancer cases per year per million population, with nationwide annual cancer cases ranging from 55 to 242. Four studies estimated risk from this source category. Two of the studies, the 5-City study and the 35-County study, estimated risk using unit risk factors for the PIC mixture. The estimated cancer rates from these two studies using these unit risk factors were 0.3 and 0.24 cancer cases per year per million population, respectively. The Southeast Chicago study estimated concentrations of the full class of POM compounds, and then estimated risk by multiplying the POM concentrations by BaP unit risk factor. (As that study noted: "While some POM compounds are probably more carcinogenic and other POM compounds are less carcinogenic, this approach in effect assumes that the average cancer potency of the full range of POM compounds equals the cancer potency of benzo(a)pyrene.") The Southeast Chicago study, using this approach, estimated a cancer rate of 0.29 cancer cases per year per million population.

The 35-County study and IEMP-Kanawha Valley study estimated risk by applying the BaP unit risk factor to BaP concentrations. This resulted in similar estimates of cancer risk -- 0.013 and 0.018 cancer cases per year per million population. The 35-County study also estimated cancer risk by applying the Six-Month Study's unit risk factor for PIC to BaP concentrations. The resulting cancer rate was 1.01 cancer cases per year per million population.

As noted earlier, the approach favored in this study for estimating risk from PIC is to use those estimates based on PIC unit risk factors for specific mixtures. Both the 35-County study and the 5-City study used this approach. Their resulting estimates of cancer rates were similar -- 0.24 and 0.3 cancer cases per year per million population. Applying these rates to total U.S. population results in an estimated 58 to 72 cancer cases per year. The Southeast Chicago study used a slightly different approach, which resulted in an estimated cancer rate of 0.29 cancer cases per year per million population (or, when extrapolated nationwide, approximately 70 cancer cases per year nationwide). Overall, it was felt that the 5-City study provided a better accounting of this source category then either of the two studies. Thus, its estimated cancer rate was used for calculating the best estimate of nationwide cancer risk from PIC emissions from woodsmoke/woodstoves.

For the remaining stationary source categories, there is little individual risk or differences in estimates of that risk. Two studies estimated risk from coal and oil combustion. The Coal and Oil Combustion study estimated risk to be approximately 1.1 cancer cases per year nationwide using the BaP unit risk factor applied to BaP emissions. Using the cancer rate estimated in the 5-City study, nationwide risk was estimated to be approximately 0.43 cancer cases per year. The 5-City study applied PIC unit risk factors that were specific to the source category. These two studies created a range of 0.43 to 1.1 annual cancer cases nationwide. Because it was based on the approach preferred in this study, the best estimate of nationwide risk was selected as 0.43 cancer cases per year. In either case, the relative magnitude is fairly small.

Only one study, the 5-City study, estimated risk from the "iron and steel" source category. The estimated cancer cases in that study was 0.34 cancer cases per year, and resulted from just one of the five cities studied. Since iron and steel facilities are not limited to that one city, a nationwide estimate of 5 cancer cases per year was calculated by applying the cancer rate of 0.022 cancer cases per year per million population to the total U.S. population (240 million). The estimate of 5 cancer cases per year is viewed as an upper limit.

Finally, the other remaining stationary source categories showed very little annual incidence or were reported in only one study (e.g., sewage sludge incinerators). The analysis, therefore, did not try to further refine these estimates.

In summary, the best estimates of annual cancer cases based on modeled estimates were: 346 to 1,028 from motor vehicles; 72 from woodsmoke/woodstoves; less than 5 from iron and steel sources; 1.5 from sewage sludge incinerators; 13 from "other" sources; and 1.5 from the other remaining source categories. The total cancer risk from PIC based on the modeled estimates is thus estimated to be 438 to 1,120 cancer cases per year.

Point Estimate. The estimates of risk from ambient-measured concentrations in the studies examined were based on applying either the BaP unit risk factor to BaP concentrations or the Six-Month Study's PIC unit risk factor to BaP concentrations. Since it was felt that the newer approaches that use unit risk factors estimated from PIC mixtures from specific sources are an improvement over those two approaches, the estimates of cancer incidence from PIC were selected based on the modeled estimates using the newer approaches. Thus, the estimate of nationwide annual cancer incidence was selected to be 438 to 1,120 cancer cases per year. This range results from the inability at this time to select a single unit risk factor for diesel particulates. Further, these estimates in themselves remain highly uncertain.

Trichloroethylene. Emissions of trichloroethylene (TCE) have been identified as coming from the production of trichloroethylene, ethylene dichloride/vinyl chloride, polyvinyl chloride, and vinylidene chloride. The majority of TCE is used as a solvent for degreasing operations, the largest source of TCE emissions. Other sources include chemical distributors, POTWs, and solvent usage in adhesives, paints, and coatings.[10]

Fourteen studies estimated cancer risk from TCE (see Table B-26). Three studies relied on ambient measured concentrations to estimate risk; the others used modeled concentrations. As seen in Table B-26, the majority of TCE emission sources have been included in one or more studies.

Ambient Estimates. The Ambient Air Quality study, the IEMP-Baltimore study, and the South Coast study used ambient measured concentrations to estimate cancer risk. The Ambient Air Quality study used data from 25 locations to estimate risk. Average population weighted annual TCE concentrations of 1.50 $\mu g/m^3$ and 0.2 $\mu g/m^3$ for urban and rural areas, respectively, were used to estimate risk. The IEMP-Baltimore study used average annual ambient data from 10 locations. The range of concentrations was from 0.2 to 3.9 $\mu g/m^3$, with a population weighted average of 0.71 $\mu g/m^3$. The South Coast study showed a range of concentrations from 0.53 to 2.12 $\mu g/m^3$, and a weighted annual average concentration of 1.7 $\mu g/m^3$. The latter two studies are best viewed as reflecting the potential geographic variation between urban areas. For a nationwide estimate, the Ambient Air Quality study was selected as the best estimate.

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[10] U.S. EPA. Survey of Trichloroethylene Emission Sources. EPA-450/3-85-021. July 1985.

TABLE B-26

ESTIMATED ANNUAL CANCER CASES FROM TRICHLOROETHYLENE BY SOURCE CATEGORY

SOURCE CATEGORY	INDIVIDUAL STUDY							
	Ambient Air Quality	NESHAP/ ATERIS	Drinking Water Aerators	POTWs	TSDFs	Waste Oil Combustion	Thirty-five County	Five City
Miscellaneous/ Unspecified		0.36^c (0.0015)					0.105 (0.0022)	0.003 (0.00019)
Aerators			0.0043 (0.000018)					
POTWs				0.39 (0.0016)			0.092 (0.0019)	
TSDFs					0.85 (0.0035)			
Waste Oil Combustors						negligible	negligible	
Solvent Use/ Degreasers		3.66^c (0.015)					1.88 (0.04)	0.18 (0.011)
Chemical Mfg.		0.0011^e (0.000004)						0.0003 (0.000001)
Municipal Landfills								
TOTALS								
MODELED		0.004-4.02 (0.000017-0.0168)	0.0043 (0.000018)	0.39 (0.0016)	0.85 (0.0035)	negligible	2.07 (0.044)	0.185 (0.012)
AMBIENT	7 (0.029)							

TABLE B-26 -- concluded

ESTIMATED ANNUAL CANCER CASES FROM TRICHLOROETHYLENE BY SOURCE CATEGORY

SOURCE CATEGORY	INDIVIDUAL STUDY						NATIONWIDE	
	IEMP-Baltimore	IEMP-Kanawha Valley	IEMP-Philadelphia	IEMP-Santa Clara	Southeast Chicago	South Coast	RANGE[a]	POINT ESTIMATE[b]
Miscellaneous/ Unspecified			0.00035[d] (0.0002)	x			<1.1	<1.1
Aerators				x			0.0043	0.0043
POTWs			negligible	x	negligible		<0.5	<0.5
TSDFs					0.00014 (0.00036)		0.09-0.85	0.85
Waste Oil Combustors		negligible					negligible	negligible
Solvent Use/ Degreasers		0.001 (0.011)	0.017 (0.01)	x	0.0029 (0.0073)		1.8-9.6	2-10
Chemical Mfg.		0.0003 (0.003)					<0.7	<0.7
Municipal Landfills				x			--	--
TOTALS								
MODELED		0.0034 (0.034)	0.017 (0.010)	0.003 (0.0019)	0.003 (0.0076)		5-13	5-13
AMBIENT	0.026 (0.017)					0.43 (0.039)	4-9	7

Footnotes to Table B-26.

NOTE: Numbers in parentheses are annual cancer cases per million population. For nationwide studies, annual cancer cases were divided by 240 million, unless otherwise noted. For studies with smaller geographic scopes, the annual cancer cases were divided by the study's population.

NOTE: An "x" in a column indicates that the source category was considered in the study, but a specific cancer risk for the source category was not indicated.

[a] The numbers in this column were calculated by taking the lowest and highest incidence rates for a source category and multiplying it by 240 (1986 U.S. population in millions). The total for this column is the summation of the low end of the range and the sum of the high end of the range.

[b] The numbers in this column present the results of the reduction analyses. In most instances, a point estimate of nationwide annual cancer incidence was derived for each pollutant/source category combination. In some instances, a point estimate could not be reasonably derived. For these instances, as narrow a range as possible of nationwide annual cancer incidence was estimated, and such ranges appear in this column. The text discusses how these point estimates and ranges were derived.

[c] Based on original NESHAP study in which 91% of emissions were attributed to solvent use and assuming cancer cases are proportional to emissions.

[d] Garment manufacturing.

[e] Includes chloro HC production, EDC production, paint stripping, and photoresistor stripping.

Modeled Estimates. Summing across source categories from the studies that used modeled concentrations yields a nearly identical range of nationwide cancer estimates as that presented by the ambient concentrations. The major significant risk source appears to be solvent usage/degreasing, which is consistent with this source category being identified as the major user of TCE. This source category shows a range of nationwide risk between 2 and 10 cancer cases per year. The higher risk estimate is from the 35-County study; the lower risk estimate is from both the IEMP-Philadelphia and the Southeast Chicago studies. The larger geographic scope of the 35-County study may suggest that its cancer rate of 0.04 cancer cases per year per million is a more reasonable rate to extrapolate to a national estimate. On the other hand, the counties selected in the 35-County study were selected, in part, for presence of known sources, and may be biased on the high side, although this is less likely to occur for an area source such as degreasing than for a point source. If the cancer rate for solvent use/degreasing from the other four studies is used (i.e., approximately 0.01 cancer cases per year per million population), the range of estimated cancer cases narrow to 4 to 6 per year. (Within the 5-City study, individual cities had estimated cancer rates between 0.005 and 0.051 annual cancer cases per million population.)

Point Estimate. The range of estimated cancer incidence from both ambient-measured and modeled concentrations is relatively narrow (4 to 9 and 5 to 13 cancer cases per year, respectively.) The wider range could probably be accepted as is for a reasonable nationwide estimate. As noted above, the range could be narrowed to 4 to 6 using the lower, but consistent, cancer rate of 0.01 cancer cases per year per million population for solvent use/degreasing. For ambient-measured estimates, the Ambient Air Quality study's estimate of 7 cancer cases per year is considered the best estimate. Based on these considerations, the 7 cancer cases per year estimated by the Ambient Air Quality study is selected as the estimate of nationwide annual cancer incidence due to exposure to trichloroethylene.

Vinyl Chloride. Nine studies included vinyl chloride as a pollutant of concern (see Table B-27). Very few of the same source categories were examined by more than one study. Further, four of the studies had general, nonspecific source categories. Except for the Ambient Air Quality study, modeled ambient concentrations were used to estimate cancer risk.

Modeled Estimates. The range of nationwide risk has been estimated to be between 6 and 25 cancer cases per year. The largest reported risk estimate (19 cancer cases per year) is from the NESHAP/ATERIS data base. This estimate reflects emissions estimated from all source categories emitting vinyl chloride and not just from those source for which regulations have been developed.[11] The specific source categories are not identified in the NESHAP/ATERIS data base, other than for ethylene dichloride manufacturing. Since TSDFs and POTWs are relatively "new" source categories, it is very likely that they are not included in the NESHAP/ATERIS data base. It is unknown if sewage sludge incinerators are included in the NESHAP/ATERIS data base for vinyl chloride emissions. Thus, the best estimate of risk based on modeled estimates is estimated to be 22 to 25 cancer cases per year nationwide (the NESHAP/ATERIS data base estimate plus the estimates from TSDFs, POTWs, and sewage sludge incinerators).

Ambient Estimates. The Ambient Air Quality study used test results from 10 locations to estimate nationwide risk. These data are summarized in Table B-28. For eight of the data points, the tests actually did not indicate any vinyl chloride; only the Institute, W.V.

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[11] U.S. EPA. Estimation of the Public Health Risks Associated with Exposures to Ambient Concentrations of 87 Substances. July 1984. Appendix A. Public Health Risks Associated with Substances Listed Under Section 112 of the Clean Air Act.

TABLE B-27

ESTIMATED ANNUAL CANCER CASES FROM VINYL CHLORIDE BY SOURCE CATEGORY

	INDIVIDUAL STUDY					
SOURCE CATEGORY	Ambient Air Quality	NESHAP/ ATERIS	Drinking Water Aerators	Sewage Sludge Incinerators	TSDFs	Thirty-five County
Chemical Manufacturing		0.0051[c] (0.000022)				
Aerators			negligible			
Sewage Sludge Incinerators				2.7 (0.011)		
TSDFs					0.023 (0.0001)	
PVC and ED/VC Manufacturing		18.5 (0.077)				
Unspecified						0.11 (0.0023)
POTW's						0.68 (0.014)
TOTALS						
MODELED		0.0051-18.5 (0.000021-0.077)	negligible	2.7 (0.011)	0.023 (0.0001)	0.79 (0.017)
AMBIENT	13 (0.054)					

TABLE B-27 -- concluded

ESTIMATED ANNUAL CANCER CASES FROM VINYL CHLORIDE BY SOURCE CATEGORY

SOURCE CATEGORY	INDIVIDUAL STUDY			NATIONWIDE	
	Five City	IEMP-Kanawha Valley	Southeast Chicago	RANGE[a]	POINT ESTIMATE[b]
Chemical Manufacturing	0.00037 (0.00002)	negligible		<0.0055	--
Aerators				negligible	negligible
Sewage Sludge Incinerators				2.7	2.7
TSDFs			negligible	0-0.023	0.023
PVC and ED/VC Manufacturing				18.5	18.5
Unspecified	0.013 (0.0008)		negligible	0-0.6	0-0.6
POTW's				3.49	3.5
TOTALS					
MODELED	0.0136 (0.0009)	negligible	negligible	6.2-24.7	25
AMBIENT				13	13

NOTE: Numbers in parentheses are annual cancer cases per million population. For nationwide studies, annual cancer cases were divided by 240 million, unless otherwise noted. For studies with smaller geographic scopes, the annual cancer cases were divided by the study's population.

[a] The numbers in this column were calculated by taking the lowest and highest incidence rates for a source category and multiplying it by 240 (1986 U.S. population in millions). The total for this column is the summation of the low end of the range and the sum of the high end of the range.

[b] The numbers in this column present the results of the reduction analyses. In most instances, a point estimate of nationwide annual cancer incidence was derived for each pollutant/source category combination. In some instances, a point estimate could not be reasonably derived. For these instances, as narrow a range as possible of nationwide annual cancer incidence was estimated, and such ranges appear in this column. The text discusses how these point estimates and ranges were derived.

[c] Ethylene dichloride (EDC) manufacturing.

[d] Lower estimate assumes sewage sludge incinerators are included in the NESHAP/ATERIS data base.

and the Baton Rouge, LA, tests provided actual measured concentrations. For six of the eight tests for which no concentrations were actually measured, the Ambient Air Quality study assumed concentrations to be one-half of the limit of detection (LOD) of the tests. In reality, the actual concentrations could be from 0 $\mu g/m^3$ to approximately 2.5 $\mu g/m^3$. For the other two tests for which no vinyl chloride was measured, no LOD values were indicated. For these two locations, the Ambient Air Quality study assigned a value of 0 $\mu g/m^3$. While specific point sources have not been identified in California, there are at least two known point sources in Baton Rouge, LA. This likely accounts for concentrations being high enough to actually measure. On the other hand, the IEMP-Kanawha Valley study identifies a single point source, located in Nitro, WV, but no sources in Institute, WV. This appears to be at least confusing with the ambient data in Table B-28, which shows the highest concentration in Institute, WV. The IEMP-Kanawha Valley study did find negligible concentrations in Nitro, which is consistent with the table if the actual concentration is below the LOD of the test method.

Point Estimate. Given the paucity and suspect nature of the ambient data, the risk estimated using modeled concentrations was selected as the estimate of cancer cases nationwide. Thus, nationwide risks from vinyl exposure to chloride emissions are estimated to be 25 cancer cases per year.

TABLE B-28

VINYL CHLORIDE CONCENTRATIONS USED IN THE AMBIENT AIR QUALITY STUDY

LOCATION	Concentration ($\mu g/m^3$)	NOBS[a]
Fremont, CA	1.278[b]	1
Mountain View, CA	1.278[b]	1
Napa, CA	1.278[b]	1
Redwood City, CA	1.278[b]	1
San Leandro, CA	1.278[b]	1
Vallejo, CA	1.278[b]	1
Las Vegas. NV	0[c]	2
Institute, WV	2.442	1
Nitro, WV	0[c]	5
Baton Rouge, LA	1.41	1

[a] NOBS = number of site-years satisfying the minimum data requirements of the Ambient Air Quality study.

[b] These values are based on one-half of the limit of detection of the test method.

[c] Tests did not indicate any vinyl chloride. Limit of detection for the test methods were not reported.

Vinylidene chloride. Emission sources of vinylidene chloride (VDC) include the production of VDC, perchloroethylene and trichloroethylene, 1,1,1-trichloroethane, VDC polymers and copolymers, and chloroacetyl chloride. In addition, VDC emissions occur from waste treatment, storage, and disposal facilities.[12] Five studies included VDC as a pollutant of concern (see Table B-29). Four of the studies used modeled ambient concentrations and one study, the Ambient Air Quality study, used ambient measured concentrations.

Modeled Estimates. The three specified source categories covered by the three studies are a portion of the known sources of VDC emissions, but are expected to be the major emitters. The two specified source categories (i.e., VDC polymer and VDC monomer) under the NESHAP/ATERIS data base are expected to be sources covered by the "unspecified" source category. Thus, the most likely estimate for risk from the NESHAP/ATERIS data base is 0.05 cancer cases per year. As the facility modeled in the Kanawha Valley does not appear in the NESHAP/ATERIS data base, the three modeled estimates can be summed. The IEMP-Kanawha Valley facility is not known as to the type of manufacturing process, and as it is a point rather than an area source, one cannot reasonably extrapolate cancer risk to larger geographic areas. Thus, it is more reasonable to add the cancer risk from the study rather than apply its cancer rate (of 0.001 annual cancer cases per year per million population) to the entire U.S. population in estimating nationwide incidence. Given these considerations, a nationwide cancer risk of approximately 0.5 cancer cases per year is estimated from the modeled estimates.

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[12] U.S. EPA. Locating and Estimating Air Emissions from Sources of Vinylidene Chloride. EPA-450/4-84-007K. September 1985.

TABLE B-29

ESTIMATED ANNUAL CANCER CASES FROM VINYLIDENE CHLORIDE BY SOURCE CATEGORY

SOURCE CATEGORY	INDIVIDUAL STUDY					NATIONWIDE	
	Ambient Air Quality	NESHAP/ ATERIS	TSDF's	IEMP- Kanawha Valley	Southeast Chicago	RANGE[a]	POINT ESTIMATE[b]
VDC Polymer		0.017 (0.000071)				--	--
VDC Monomer		0.0023 (0.00001)				--	--
Chemical Manufacturing				0.001 (0.01)		0.001[c]	0.001
TSDF's			0.49 (0.002)		negligible	0-0.49	0.49
POTWs					negligible	negligible	negligible
Unspecified		0.05[d] (0.0002)			negligible	0.05	0.05
TOTALS							
MODELED		0.019-0.05 (0.00008-0.0002)	0.49 (0.002)	0.001 (0.01)	negligible	0.05-0.5	0.5
AMBIENT	10 (0.04)					10	10

NOTE: Numbers in parentheses are annual cancer cases per million population. For nationwide studies, annual cancer cases were divided by 240 million, unless otherwise noted. For studies with smaller geographic scopes, the annual cancer cases were divided by the study's population.

[a] The numbers in this column were calculated by taking the lowest and highest incidence rates for a source category and multiplying it by 240 (1986 U.S. population in millions). The total for this column is the summation of the low end of the range and the sum of the high end of the range.

[b] The numbers in this column present the results of the reduction analyses. In most instances, a point estimate of nationwide annual cancer incidence was derived for each pollutant/source category combination. In some instances, a point estimate could not be reasonably derived. For these instances, as narrow a range as possible of nationwide annual cancer incidence was estimated, and such ranges appear in this column. The text discusses how these point estimates and ranges were derived.

[c] Due to unknown nature of chemical facility, the incidence rate from the IEMP-Kanawha Valley study was not extrapolated nationwide.

[d] This number likely includes VDC polymer and VDC monomer sources as well as other unspecified sources.

Ambient Estimates. The Ambient Air Quality study estimates 20 times this risk (10 cancer cases per year versus 0.5 per year). The results of the Ambient Air Quality study are based upon ambient measured data from ten locations. At least four of these locations have known VDC emitters (Los Angeles, Chicago, Charleston, W.V., and Sacramento, CA.). The ambient concentrations for these four cities were 0.02, 0.088, 0.03, and 0.27 $\mu g/m^3$, respectively, for a per city average of 0.10 $\mu g/m^3$. Based on locations identified in "Locating and Estimating Air Emissions from Source of the Vinylidene chloride," (EPA-450/4-85-007k), none of the other six cities have point sources of VDC. Ambient concentrations in these seven other cities ranged from 0.036 to 0.124 $\mu g/m^3$, for a per city average of 0.066 $\mu g/m^3$. Given the known locations of VDC point source emitters, it is not surprising that the four-city average concentration is larger than the six-city average concentration, although it is somewhat surprising that two of the four cities with known VDC sources had the two lowest concentration reading of all ten locations.

Point Estimate. Considering the above information, a range of cancer cases of between 0.5 and 10 per year nationwide is created. Although more information on VDC sources and a broader data base would be desirable, the Ambient Air Quality study's results (10 cancer cases per year) were selected as the estimate of cancer risk to total VDC exposure at this time.

APPENDIX C

SUMMARIES OF POLLUTANT-SPECIFIC AND SOURCE-SPECIFIC STUDIES

(INCLUDING NONCANCER HEALTH RISK PROJECT ON AIR TOXICS)

This appendix presents summaries of ongoing EPA studies that are related to specific pollutants and source categories. Most of these studies are related to the development of national emission standards for hazardous pollutants (NESHAPs). In addition, a summary of the EPA study on noncancer health risks of air toxics is provided (Noncancer Health Risk Project). An index to these studies is presented below.

Study	Page No.
1. Asbestos	C-3
2. Coal and Oil Combustion	C-6
3. Drinking Water Aerators	C-12
4. Gasoline Marketing	C-17
5. Hazardous Waste Combustors	C-24
6. Municipal Waste Combustors	C-34
7. Municipal Solid Waste Landfills	C-41
8. Publicly Owned Treatment Works (POTWs)	C-42
9. Radionuclides	C-46
10. Sewage Sludge Incinerators	C-50
11. Superfund Sites	C-55
12. Treatment, Storage, and Disposal Facilities for Hazardous Waste (TSDF)	C-56
13. Waste Oil Combustors	C-61
14. Woodstoves	C-67
15. Noncancer Health Risk Project	C-70

Asbestos

The Office of Air and Radiation promulgated the initial asbestos NESHAP in 1973 and revised the rule in 1975, 1978, and 1984. The purpose of this asbestos project is to review the current NESHAP, assess its effectiveness and revise the rule as necessary. The current NESHAP covers asbestos milling, manufacturing and fabricating, removal of asbestos prior to renovation or demolition, the disposal of asbestos waste, and the use of asbestos in spraying, insulation, and asphalt-concrete for roadways.[1] The standard was based on a qualitative assessment of the risk from exposure to asbestos. With the development of a unit risk estimate for asbestos, it is now possible to make a quantitative assessment of risk.

The risk assessment has been performed to assess the risk from the current asbestos emissions as well as the regulatory alternatives (Reference 1). Table C-1 presents the current risks and the minor revisions alternative that would promote full compliance to the NESHAP. Other alternatives (not presented) reduce risk to negligible levels.

Asbestos emissions from milling, manufacturing and fabricating and waste disposal from these facilities were modeled using the point source algorithm of the Human Exposure Model (HEM). Plant specific data were obtained by Section 114 letters for the plants with the highest maximum lifetime risk and annual incidence. Two of these plants were modeled using ISCLT/LONGZ. The maximum individual lifetime risk reported in Table C-1 for manufacturing results from this more detailed modeling.

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[1] Due to the discontinued use of asbestos in spraying, insulation, and asphalt concrete roadways, emissions and, therefore, risks are thought to be negligible. The regulation does not address unpaved roadways containing asbestos-contaminated gravel, which occurs naturally in some areas. This was concluded a local problem and risk was not assessed.

TABLE C-1

ESTIMATES OF INCIDENCE AND INDIVIDUAL RISK DUE TO ASBESTOS EMITTED INTO THE AIR[a]

	Maximum Individual Lifetime Risk		Estimated Excess Annual Lung Cancer and Mesotheliomas	
Source Categories	Full Compliance	Current Compliance[b]	Full Compliance	Current Compliance[b]
Milling	3×10^{-5}	same	0.004 - 0.005	same
Disposal	6×10^{-9}	same	<0.0001	same
Manufacturing	2×10^{-3}	same	0.3 - 0.7	same
Fabrication	2×10^{-4}	same	0.05 - 0.2	same
Renovation,				
Removal	3×10^{-7}	6×10^{-7}	0.003	0.0071
Disposal	6×10^{-8}	3×10^{-5}	0.0007	0.35
Demolition,				
Removal	2×10^{-5}	4×10^{-5}	0.3	0.5
Disposal	1×10^{-5}	7×10^{-3}	0.1	80
TOTAL			0.7 - 1.2	81.6

Source: Reference 1, pages A-28, A-32, A-35, and A-36.

[a] Please refer to footnote 1, page C-3, for a list of caveats and an explanation of the methodology used to generate these results.

[b] The large number of sources and inadequate enforcement resources have resulted in noncompliance with the demolition and renovation (including waste disposal) standards. The Stationary Source Compliance Division estimated compliance in 1985 at about 50 percent. The risk estimates in parentheses were estimated under the assumption that only 50 percent of the demolitions and 80 percent of the renovations were in compliance.

Asbestos emissions from removal and waste disposal during renovation and demolition activities were modeled using the area source algorithm of HEM. Asbestos emissions were assigned to each county based on the population of that county. This process generated the annual incidence figures. The maximum individual lifetime risk was generated assuming that emissions assigned to the county with the highest population density were emitted from a single point source. This technique overestimates risk.

The renovation and demolition source categories for asbestos are unique because it is estimated that only 80 percent and 50 percent are in compliance, respectively, to the current NESHAP. This makes baseline risk different from full compliance to the current NESHAP.

Asbestos is a known human carcinogen. The unit risk estimate is based on several human studies. The health data base for asbestos is much better than most toxicant data bases. It is important to note, however, that in order for asbestos to cause lung cancer or mesothelioma the fibers must be respirable. Respirable refers to fibers small enough to enter small airways. Lacking fiber size distribution information, 100 percent respirability was assumed. The larger nonrespirable particles may comprise a large portion of the emissions. The emissions of respirable asbestos and thus estimated risk could be greatly overestimated.

References

1. U.S. Environmental Protection Agency, Emission Standards and Engineering Division. National Emission Standards for Asbestos-Background Information for Proposed Standards. Draft. March 5, 1987.

Coal and Oil Combustion

The Environmental Protection Agency's Office of Air Quality Planning and Standards has evaluated on a national scale toxic emissions from utility, industrial, commercial and residential combustion units (Reference 6). These four combustion sectors, briefly described in Table C-2, are known to emit several carcinogenic compounds, of which 9 were specifically included in this effort. These 9 pollutants are: acetaldehyde, acrolein, arsenic, beryllium, cadmium, hexavalent chromium, polycyclic organic matter (POM), formaldehyde, and radionuclides. Other pollutants were not evaluated because of a paucity of emissions data. Because of the nature of the available emissions data (national averages of data with large variations), short-term exposures were not specifically considered and long-term exposures (and associated cancer risks) were given the most attention. The preliminary cancer risk assessment estimates (see Tables C-3 and C-4) indicate that the national cancer incidence is about 11 cases per year and that the maximum individual risk for all sectors is less than 10^{-4}. However, these estimates are crude and at best are considered "order of magnitude" values since the exposure techniques (described below) are not based on site-specific analysis.

As seen in Table C-2, the number of combustion units is very large and reasonably precludes site-specific analysis. However, for the utility sector, a data base which contained basic stack parameters and control technology status was available for a large majority of the plants and was used for this study. The Human Exposure (computer) Model was run for each plant in the data base in conjunction with an emissions data base containing national average emissions factors and average control efficiencies. Flat terrain was assumed for the air dispersion

TABLE C-2

BACKGROUND INFORMATION ON THE COAL AND OIL COMBUSTION SECTORS

SECTOR	NO. OF UNITS		FUEL BURNED[a]	
			COAL	OIL
	COAL	OIL	10^{12} Btu/yr (Millions of tons/yr)	10^{12} Btu/yr (Millions of barrels/yr)
Utility	987[b]	264[b]	12,500[a] (594)	1,600[a] (250)
Industrial	51,000[c]	190,000[c]	2,500[a] (105)	2,400[a] (390)
Commercial	163,000[c]	443,000[c]	115[a] (5)	840[a] (138)
Residential	430,000[d]	13,000,000[d]	77[a] (3)	1,050[a] (180)

[a] Reference 3.
[b] Reference 1.
[c] Reference 4.
[d] Reference 2.

TABLE C-3

ESTIMATED ANNUAL INCIDENCE FOR COAL AND OIL COMBUSTION BASELINE RISKS[a]

Source Category	Pollutant							TOTALS
	Arsenic	Beryllium	Cadmium	Hexavalent Chromium	POM	Formaldehyde	Radionuclides	
Utility								
Coal	0.4	0.0	0.0	0.0	0.0	0.0	0.5	0.9
Oil	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Industrial								
Coal	2.0	0.1	0.1	0.1	0.0	0.0	2.0	4.3
Oil	0.4	0.1	0.3	0.0	0.0	0.1	0.0	0.9
Commercial								
Coal	0.5	0.0	0.0	0.0	0.1	0.0	0.3	0.9
Oil	1.0	0.2	0.5	0.0	0.0	0.1	0.0	1.7
Residential								
Coal	0.8	0.0	0.0	0.0	0.9	0.0	0.0	1.7
Oil	0.2	0.1	0.2	0.0	0.0	0.1	0.0	0.5
Totals	5.3	0.5	1.1	0.2	1.1	0.2	2.8	11.1

SOURCE: Reference 1.

[a] Acrolein and acetaldehyde were evaluated, but found insignificant.

TABLE C-4

ESTIMATED MAXIMUM INDIVIDUAL LIFETIME RISKS
FOR COAL AND OIL COMBUSTION BASELINE RISKS[a]

Source Category	Pollutant							TOTALS
	Arsenic	Beryllium	Cadmium	Hexavalent Chromium	POM	Formaldehyde	Radionuclides	
Utility								
Coal	1×10^{-5}	6×10^{-7}	5×10^{-7}	7×10^{-7}	2×10^{-8}	1×10^{-7}	3×10^{-6}	2×10^{-5}
Oil	1×10^{-6}	2×10^{-7}	5×10^{-7}	3×10^{-8}	1×10^{-8}	1×10^{-7}	--	2×10^{-6}
Industrial								
Coal	4×10^{-5}	2×10^{-6}	2×10^{-6}	8×10^{-7}	2×10^{-6}	2×10^{-7}	3×10^{-6}	5×10^{-5}
Oil	7×10^{-6}	9×10^{-7}	3×10^{-6}	4×10^{-7}	3×10^{-7}	8×10^{-7}	--	1×10^{-5}
Commercial								
Coal	6×10^{-6}	3×10^{-7}	4×10^{-7}	3×10^{-7}	5×10^{-6}	1×10^{-7}	4×10^{-7}	1×10^{-5}
Oil	4×10^{-5}	5×10^{-6}	1×10^{-5}	8×10^{-7}	3×10^{-7}	2×10^{-6}	--	6×10^{-5}
Residential								
Coal	--	--	--	--	--	--	--	--
Oil	--	--	--	--	--	--	--	--
Maximum Value	4×10^{-5}	5×10^{-6}	1×10^{-5}	8×10^{-7}	5×10^{-6}	2×10^{-6}	3×10^{-6}	

Maximum Risk = 7×10^{-5}

SOURCE: Reference 1.

[a] Acrolein and acetaldehyde were evaluated, but were found insignificant.

analysis and no site-specific or geographic or seasonal adjustments were made to the emission factors. As in the case for all sectors, distinctions were made for three coal types (bituminous, anthracite, and lignite) and two different oil types (distillate and residual). For the industrial and commercial combustion units, a subset of all the boilers, a stratified random sample from the National Emissions Data System, was analyzed in a manner similar the utility sector. Because this sample of boilers were representative of boilers greater than two million Btu's per hour, an additional exposure analysis, which applied a simple area source model, was used for these very small boilers. Toxic emissions and long-term concentrations were estimated on a county-by-county basis. For the last sector, residential heating, the same approach as that used for the very small industrial/commercial boilers was applied.

For this project there are several uncertainties of note. Based on a review of the emissions data, there is a very wide range of emission factors found in the literature; however, this study assumed that average or typical emission factors were applicable at boiler site. Coal and oil combustion is known to emit a wide range of compounds, but all the pollutants evaluated in this study (a total of 9) account for less than 10 percent of the particulate matter and the volatile organic compound emissions. Thus, there is a considerable fraction of the combustion emissions of unknown toxicity. Lastly, and most important because the estimated maximum and average concentrations are low, the models by which public risks are calculated must extrapolate a health data base established from high exposure levels to public exposure levels which are several too many orders of magnitude lower.

References

1. Peters, W.D., US EPA, Pollutant Assessment Branch. Coal and Oil Combustion. July 25, 1988. 6 pages.

2. Utility Data Institute. Power Statistics Database, 1983. Developed by: Edison Electric Institute.

3. U.S. Department of Commerce, Bureau of the Census. Statistical Abstract of the United States - 1986. 106th Edition. Table 1315, page 733.

4. U.S. Department of Energy, Energy Information Administration. State Energy Data Report: Consumption Estimates, 1960-1982. May 1984.

5. U.S. Environmental Protection Agency, Industrial Environmental Research Lab. Population and Characteristics of Industrial/Commercial Boilers in the U.S. EPA-600-7/79-178a, August 1979.

6. U.S. Environmental Protection Agency, OAQPS. Coal and Oil Combustion Study: Summary and Results. External Review Draft. September 1986.

Aeration of Toxics from Drinking Water Treatment Facilities

In response to several requests from the Office of Drinking Water (ODW), the Office of Air Quality Planning and Standards (OAQPS) has assessed the cancer risk associated with aeration treatment of drinking water in the U.S. When drinking water supplies contain volatile compounds (VCs) that are toxic, the aeration process can be used very effectively to remove the VCs from the water, but at the same time, create VC emissions to the atmosphere. To date, OAQPS has evaluated 10 pollutants (listed in Table C-5) in three different studies. The preliminary risk assessment results are summarized in Table C-6. These results, which are based on a screening analysis described below, provide crude estimates and are, at best, order of magnitude estimates.

In Study Number 1 (Reference 1), the first seven chemicals in Table C-5 were evaluated from 22 existing sources with known contamination levels that were either aerating or planning to aerate their water supplies in the near future. The ODW supplied the necessary emissions and stack data, but the exact locations of the facilities were unknown. The facilities were assumed to be located in: (1) the center of the cities to which units were supplying water, and (2) in areas of flat terrain. The VC emission rates were based on actual site-specific data and the assumption of 100 percent efficient aerators. The Human Exposure Model (HEM) was used to estimate the air dispersion of the emissions, the public exposure to the emissions, and the associated cancer risks. As seen in Table C-6, risk projections were made based on the thought that the 22 selected sites were typical operations and were representative of as many as 200-500 facilities which were anticipated to be built over the next ten years. It was assumed that the aggregate

TABLE C-5

LIST OF POLLUTANTS EMITTED FROM AERATION OF DRINKING WATER TREATMENTFACILITIES WHICH HAVE BEEN EVALUATED BY OAQPS

POLLUTANT	STUDY NO.	REFERENCE NO.
Trichloroethylene	1	1
Tetrachloroethylene	1	1
1,1,1 Trichloroethane	1	1
1,2 Dichloroethane (EDC)	1	1
Carbon Tetrachloride	1	1
1,1,2,2 Tetrachloroethane	1	1
Vinyl chloride	1	1
Ethylene dibromide (EDB)	2	2
Dibromochloropropane (DBCP)	2	2
Radon	3	3

NOTE: Study numbers refer to studies listed in Table C-6.

TABLE C-6

RISK ASSESSMENT RESULTS FOR THE THREE DRINKING WATER AERATION STUDIES

Study No.	No. of Plants	No. of Pollutants	Max. Individual Lifetime Risk	Annual Incidence	Projected Annual Incidence
1	22 (existing)	All but EDB, DBCP, Radon	2×10^{-5}	0.0047	-
	200	All but EDB, DBCP, Radon	2×10^{-5}	-	0.043
	500	All but EDB, DBCP, Radon	2×10^{-5}	-	0.11
2	7	EDB & DBCP	3×10^{-6}	0.0002	-
3	20	Radon	5×10^{-5}	0.016	-
	Approx. 26000	Radon	5×10^{-5}	-	0.4[a]

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[a] Assumes all facilities using water supplies with radon concentrations > 200 pCi/L apply aeration as a control technique.

population risks were proportional to the number of plants applying aeration treatment.

In Study Number 2 (Reference 2), only two chemicals (see Table C-6) from seven sites were evaluated. However, in this case, although the analysis was conducted in a manner similar to Study Number 1, there were no projections of national or future level of aggregate risks. The site-specific contamination data were thought to be untypical of most plants in the country, since these chemicals were not usually found in drinking water supplies.

In Study Number 3 (Reference 3), the OAQPS, in conjunction with the Office of Radiation Programs (ORP), estimated cancer risks associated with potential radon emissions from the aeration process. The ODW selected 19 sites that were thought to be typical of facilities across the country plus one site that was known to have a very large radon emission rate. Many of the facilities selected, in addition to most facilities in the country, are not currently aerating their drinking water; the goal of this study was to determine the potential level of risks if many of the existing facilities would aerate their water supplies. Because of the complicated mathematics that are required to model air dispersion of radioactive emissions of both the parent isotopes and progeny of the radioactive decay process, the HEM cannot adequately estimate public exposure. So, the ORP computer models that were specifically designed for radioactive emission exposure (AIRDOS-EPA, RADRISK, DARTAB) were required. These computer models estimate radionuclide concentrations in the air, rates of deposition on the ground, and the amounts of radionuclides taken into the body via inhalation of air and ingestion of meat, milk, and fresh produce. As in the case where the HEM was used, flat terrain was assumed when running the ARDOS model.

In addition, using a technique like that used in the first study, national risk estimates were projected based on the results of the 19 facilities.

References

1. Memorandum W.D. Peters, US EPA, Pollutant Assessment Branch, and S.W. Clark, US EPA, Science and Technology Branch, to R.G. Kellam, US EPA, Science and Technology Branch. Risks Associated with Air Emissions from Aeration of Drinking Water. November 18, 1985. (Study Number 1)

2. Memorandum. W.D. Peters, US EPA, Pollutant Assessment Branch, to S.W. Clark, US EPA, Science and Technology Branch. Aeration Drinking Water Facilities - EDB and DBCP Emissions. February 18, 1986. (Study Number 2).

3. Memorandum. W.D. Peters, US EPA, Pollutant Assessment Branch, and C.B. Nelson, US EPA, Office of Radiation Programs, to S.W. Clark, US EPA, Technology Section, STB, CSD, ODW. Preliminary Risk Assessment for Radon Emissions from Drinking Water Treatment Facilities. May 1988. (Study Number 3)

Risk Assessment for the Gasoline Marketing Source Category

A cancer risk assessment was performed for the gasoline marketing source category to determine risk from high exposure and cancer incidences, due to exposures to gasoline vapor emissions. Pollutants of concern were benzene, gasoline vapors (as a collection of all components), ethylene dibromide (EDB) and ethylene dichloride (EDC). The study evaluated uncontrolled and controlled emissions from bulk gasoline terminals, bulk plants, storage tanks, and service stations. This discussion presents a summary of these risk analyses. More detailed discussion can be found in the EPA reports describing the entire analysis (see References 2 and 3).

The purpose of the overall study was to evaluate environmental impacts, costs, risks, and benefits associated with reducing emissions at gasoline marketing facilities. Many regulatory strategies were analyzed in this study. However, risk assessments centered on the evaluation of exposures for individuals living in the vicinity of gasoline marketing facilities (community exposures). Risks for these individuals were based upon emissions from bulk terminal and bulk plant storage tank and tank truck loading operations, gasoline deliveries to service stations (service station Stage I) and vehicle refueling operations (service station Stage II). The vehicle refueling analyses included not only community exposures but also self-service refueling exposures to individuals refueling their own vehicle, and occupational exposures to service station attendants.

The project is on-going and risk assessments have centered on benzene and gasoline vapor exposures. EDB and EDC are components of leaded gasoline only and were found to be very small, especially with the decline of leaded gasoline usage. Gasoline vapor risk analyses were originally based upon studies of exposures to wholly vaporized gasoline, since this was the basis of the animal exposure studies from which the risk factors were calculated. Based on review by the Science Advisory Board and on public comments received, there was some concern whether all components in wholly vaporized gasoline were indicative of actual gasoline vapor exposure. An estimate of components C_6 and higher (thought to be the components of concern in gasoline vapors) was calculated. As a result, exposure to gasoline vapors was calculated and expressed as due to total vapors and due to C_6 and higher components in gasoline vapors. Table C-7 contains a summary of unit risk factors used in the gasoline marketing analysis.

Risk estimates for all gasoline marketing source categories proved to be very difficult because of the large number of sources involved (1500 terminals, 15,000 bulk plants, and 400,000 service stations). Obviously risk assessments could not be conducted on each individual source, so a scheme of model plants and representative locations was developed.

The assessment methodology derived for bulk terminals and bulk plants were similar. A series of model plants for each source category were developed for both product storage and truck loading operations. Since these facilities are usually clustered due to access to pipelines, railways and barge transport points, clusters of complexes of facilities were developed. Several cities, of varying population sizes and densities, were selected to represent the country as a whole. The model complex selected for use in each city was developed to represent the city size (e.g., large terminals in larger cities, smaller terminals in smaller cities). Model facility complexes were placed at coordinates of

TABLE C-7

UNIT RISK FACTORS APPLICABLE TO THE GASOLINE MARKETING SOURCE CATEGORY

Pollutant	Unit Risk Factor[a]
Benzene	2.6×10^{-2}
Gasoline Vapors	
- Rat Studies	
o PUL[b]	[d] 3.1×10^{-3}
o MLE[c]	2.0×10^{-3}
- Mice Studies	
o PUL[b]	2.1×10^{-3}
o MLE[c]	1.4×10^{-3}
Ethylene Dibromide	4.2×10^{-1}
Ethylene Dichloride	2.8×10^{-2}

SOURCE: Reference 2, pages 6-2 and 6-31, and Reference 3, page 2-61.

[a] Probability of cancer incidence from exposure to 1 ppm over a 70-year lifetime.

[b] PUL = Plausible Upper Limit.

[c] MLE = Maximum Likelihood Estimate.

[d] Risk factor used as basis for gasoline vapor risk estimates in latest analysis.

known bulk loading sites within each city selected. Emission rates and heights were calculated and used as input to the Human Exposure Model (HEM) to estimate cancer incidences for individuals living in the vicinity of the model loading complex. Nationwide incidences were then calculated based on incidences for each city evaluated and the population distribution of each city size found in the country. For example, the country was divided into seven population ranges. Several cities were selected to represent each population range. The HEM results for each city within a range were averaged, and the results used to represent that range. The average exposure from each population range was weighted by the percent nationwide population in that range to obtain the nationwide exposure.

Because of the vast number of service stations and the ability to locate them virtually anywhere within a metropolitan area, the method for estimating incidences due to exposures to individuals living in the vicinity of service stations could not be based on actual locations.

Several metropolitan areas around the country were selected to represent population ranges for the nation. Within each metropolitan area, the gasoline consumption was used to estimate total emissions from service stations. These emissions were then assumed to be uniformally spread over the metropolitan area and a uniform exposure concentration was calculated. This uniform concentration was used as input to the HEM model to determine cancer incidence estimates in each of the selected metropolitan areas. Nationwide incidences were calculated by weighing the results from each population range by the percent nationwide population in that range, as was done for bulk terminals and bulk plants. Risks from high exposure were based upon calculations of exposures to individuals living near a model complex or service stations such as may be found at intersections with service stations on every corner.

Vehicle refueling self-service and occupational exposures were calculated based upon field studies to determine actual concentration experienced in the breathing zone of individuals refueling their vehicles (see Reference 1). These exposure concentrations, coupled with the risk factors and known quantities of gasoline pumped nationwide at self-service and full-service operations were then used to calculate cancer incidences.

Table C-8 presents a summary of the nationwide average annual baseline risks associated with exposures to benzene, gasoline vapors, EDB, and EDC. Lifetime risks from high exposures are based upon exposures to total gasoline vapors. Table C-9 summarizes the residual risks and risk reductions associated with the regulatory strategies revaluated in this analysis. Values for EDB and EDC are not included in the summary since they had been dropped from consideration at the time this analysis was conducted.

References

1. Clayton Environmental Consultants, Inc. Gasoline Exposure Study for the American Petroleum Institute. Job No. 18629-15. Southfield, MI. August 1983.

2. U.S. Environmental Protection Agency. Evaluation of Air Pollution Regulatory Strategies for Gasoline Marketing Industry. EPA-450/3-84-012a. July 1984.

3. U.S. Environmental Protection Agency. Draft Regulatory Impact Analysis: Proposed Refueling Emissions Regulations for Gasoline-Fueled Motor Vehicles - Volume I Analysis of Gasoline Marketing Regulatory Strategies. EPA-450/3-87-001a. July 1987.

TABLE C-8

SUMMARY OF ESTIMATED BASELINE CANCER RISKS FOR THE GASOLINE MARKETING INDUSTRY[a]

Facility Category	Lifetime Risk From High Exposure[b]	Average Annual Cancer Cases				
		Benzene	Gasoline Vapors		EDB	EDC
			Total	C_6		
Bulk Terminals	5.7×10^{-3}	0.1	3.5	0.9	0.0005	0.0006
Bulk Plants	2×10^{-4}	0.05	1.4	0.4	0.0002	0.0002
Service Stations						
• Community Exposure						
- Stage I	6.7×10^{-5}	0.1	3	0.8	-[c]	-
- Stage II	1×10^{-4}	0.4	10	2.5	-	-
(Total)	(1.6×10^{-4})	(0.5)	(13)	(3.3)	(0.001)	(0.001)
• Self-Service	8×10^{-5}	4.4	33	8.3	0.006	0.008
Total Public Incidence		5.1	51	13	0.008	0.01
Occupational (Service Stations)	4×10^{-3}	1.7[b]	17[b]	4.3	-	-
Total Incidence for Gasoline Marketing Source Category		6.8	68	17	0.008	0.01

SOURCE: Reference 2, page 6-31 and Reference 3, page 2-63.

[a] Baseline risks are those projected throughout the study period (1988-2020) with no additional controls.

[b] Based on plausible upper limit for total gasoline vapors.

[c] Not calculated.

TABLE C-9

IMPACT ON ANNUAL CANCER INCIDENCE DUE TO GASOLINE MARKETING REGULATORY STRATEGIES (1988-2020)

Regulatory Strategy (with Size) Exemptions)	Average Annual Residual Incidence (Benzene/Gas Vapors[a])						Reduction From Baseline[b]
	Bulk Terminals	Bulk Plants	Service Stations	Self-Service	Occupational	Total[b]	
Baseline	0.1/4	0.05/1	0.5/13	4/33	2/17	7/68	-
Stage I - Nationwide	0.09/2	0.02/0.5	0.4/11	4/33	2/17	7/64	0.1/4
Evaporative Controls	0.1/4	0.05/1	0.5/13	4/33	2/17	7/68	0.4/6[c]
Stage II - 27 Areas	0.1/4	0.05/1	0.4/11	4/29	2/15	6/58	1/10
Stage II - 27 Areas Evaporative Controls	0.1/4	0.05/1	0.4/11	4/29	2/15	6/58	1/14-16[c]
Stage II - Nationwide[d]	0.1/4	0.05/1	0.3/8-9	2-3/14-20	1/10-12	3-4/36-46	4-4/22-32
Stage II - Nationwide[d] Evaporative Controls	0.1/4	0.05/1	0.3/8-9	2-3/14-20	1/10-12	3-4/36-46	4-4/28-38[c]
Onboard Nationwide	0.1/4	0.05/1	0.2/7	1/10	0.8/9	3/30	5/43[c]
Stage II - 27 Areas Onboard Nationwide	0.1/4	0.05/1	0.2/7	1/9	0.8/8	2/29	5/45[c]

SOURCE: Reference 3, page 2-64.

[a] Values shown for total gas vapors. Total gas vapors can be converted to C_6 gas vapors by dividing by 4.

[b] Results may not add up exactly due to rounding.

[c] Evaporative controls yield incidence reductions from vehicle operations and not from gasoline marketing.

[d] Range of values represents the range of efficiencies found between a program of minimal enforcement (62 percent) and an active (annual) enforcement program (86 percent) and the range of equipment phase-in schedules (3-7 years). If no range is indicated, the upper and lower values vary by less than 10 percent and the average is presented.

Hazardous Waste Combustors

Wastes containing hazardous materials are commonly burned in incinerators, boilers, and industrial furnaces. The U.S. Environmental Protection Agency has estimated toxic emissions from hazardous waste incinerators as part of regulations under the Resource Conservation and Recovery Act (RCRA) and from the burning of hazardous wastes in boilers or industrial furnaces, also as part of regulations under RCRA. Table C-10 summarizes the toxic emissions being regulated from hazardous waste combustors.

For incinerators, boilers, and industrial furnaces, EPA has determined that risks from the burning of hazardous wastes in these devices can be unacceptable under reasonable, worst-case circumstances.[2] For purposes of the rules, EPA defined unreasonable risk to be either: (1) an exceedance of incremental lifetime cancer risk of greater than 1 x 10^{-5} to the potential maximum exposed individual (MEI) for toxic metal and organic compound emissions and other carcinogens; or (2) an exceedance at the MEI of Reference Air Concentrations for noncarcinogens established at 25 percent of the Reference Dose.[3]

Risk Assessment. For hazardous waste incinerators, a risk assessment was performed under existing baseline and post-compliance conditions for 82 incinerators. The risk assessment was performed for three carcinogenic metals (arsenic, cadmium, and hexavalent chromium),

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[2] Components of the reasonable, worst-case circumstances included concentrations of constituents in the incinerated waste, combustion capacity or feed rate, partioning of metals to bottom ash, collection efficiency of emission control equipment, and local terrain and meteorological conditions.

[3] Except for lead and hydrogen chloride. The exceedance for lead was set at 10 percent of the national ambient air quality standard for lead, and for hydrogen chloride the reference air concentration was based directly on inhalation exposure studies. (Reference 2, page 13).

TABLE C-10

TOXIC EMISSIONS SUBJECT TO HAZARDOUS WASTE COMBUSTOR REGULATIONS

Pollutant
Antimony
Arsenic
Barium
Beryllium
Cadmium
Chromium (VI)
Hydrogen Chloride
Lead
Mercury
Principal organic hazardous constituents (POHCs)
Products of incomplete combustion (PIC)[a]
Silver
Thallium

SOURCE: Reference 3, Exhibit 7-3.

[a] Includes the following compounds:

benzene
perchloroethylene
carbon tetrachloride
1,1,1-trichloroethane
1,1,2-trichloroethane
chloroform
trichloroethylene
1,2-dichloroethane
1,1-dichloroethylene
1,1,2,2-tetrachloroethane
1,2-dichloroethylene

principal organic hazardous compounds (POHCs), and products of incomplete combustion (PIC), and for noncarcinogens (hydrogen chloride, lead, barium, and mercury).[4] For the three carcinogenic metals, both lifetime cancer to the maximum exposed individual and the annual cancer incidence attributable to all metals at each facility were estimated.

Emissions of the six metals from each facility were approximated by using estimates of: (1) the quantity of hazardous waste combusted by RCRA code, (2) the estimated fraction of metals in each RCRA code, (3) the fraction of each metal segregated as bottom ash and stack emissions, and (4) metal removal efficiencies for in-place air pollution control devices. Maximum and area-wide ambient concentrations were predicted using dispersion modeling for ten hypothetical facilities plus the actual facility at 24 different sites. The unit cancer risk values were obtained from EPA's Carcinogen Assessment Group. Population data for estimating the number of exposed individuals was obtained from U.S. Census data available from the Office of Toxic Substance's Graphical Exposure Modeling System (GEMS).

For hazardous waste boilers and industrial furnaces, the risk assessment performed also examined both existing baseline and post-compliance conditions. The analysis predicted health risks from stack releases and resulting atmospheric concentrations of POHCs, PICs, metals, and hydrogen chloride. Both cancer and non-cancer health effects were considered; however, estimates were only made for the aggregate number of cancer cases. Both maximum exposed individual risk and aggregate cancer cases over 70 years were estimated.

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[4] Lead has since been designated as a B_2 carcinogen, and is not included in this report's estimate of cancer risk.

In estimating cancer risk from boilers and industrial furnaces, risks were calculated assuming two types of hazardous wastes being burned (a base case waste and a high risk waste)[5] and two levels of control device performance (a base case and a pessimistic performance level). The analysis assumed that all toxic compounds in the waste are emitted unless destroyed or removed by air pollution control devices. For metals, the risk calculations assume that all metals are present in stack emissions and that none remain in the ash. Estimates of ambient concentrations were made using the Industrial Source Complex Long-Term (ISCLT) Model. Site meteorology and population data were obtained from GEMS.

Results. Table C-11 summarizes the estimated excess cancer cases from incinerators burning hazardous wastes and Table C-12 for boilers and furnaces burning hazardous wastes. Table C-13 summarizes the distribution of MEI risk levels for boilers and furnaces.

Incinerators. The estimated annual baseline cancer incidence for the three carcinogenic metals, aggregated across all 167 sites at which EPA estimates such metals are contained in hazardous waste that are incinerated, is approximately 0.03, or roughly 2 cases in 70 years for the U.S. as a whole. Hexavalent chromium accounts for over half of the predicted annual cancer incidence, with cadmium and arsenic contributing approximately 34 percent and 13 percent, respectively. Twenty-two

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[5] "Base case" waste is not a "typical" waste in that it contains both metals and organic constituents. It contains metals equal to the 50th percentile values for wastes that contain metals (rather than the 50th percentile values for all hazardous wastes, including those containing no metals). Both POHC and chlorine content are higher than reported for a large number of actual waste streams. Thus, the hypothetical base case waste could result in greater risk when burned than many types of hazardous waste that may be burned for fuel. "High risk" waste consists of 90 percent organic constituents and the 90th percentile levels for metals. (Reference 3, p. 5-6)

TABLE C-11

ESTIMATE OF EXCESS ANNUAL AND LIFETIME CANCER INCIDENCE FROM HAZARDOUS WASTE COMBUSTORS - INCINERATORS

Pollutant	Annual Cases		Cases per 70 Years	
	Baseline	After Compliance[a]	Baseline	After Compliance[a]
Arsenic	0.005	0.003 (0.001)	0.318	0.184 (0.103)
Cadmium	0.012	0.007 (0.004)	0.824	0.509 (0.299)
Chromium (VI)	0.018	0.009 (0.005)	1.248	0.603 (0.368)
Total	0.034	0.019 (0.011)	2.39	1.297 (0.771)

SOURCE: Reference 2, pages 128 and 132.

[a] Numbers not in ( ) represent compliance with the proposed rule that would require controlling emissions such that a maximum individual risk level of 1×10^{-5} is not exceeded at any individual facility. Numbers in ( ) represent control of emissions such that a maximum individual risk level of 1×10^{-6} is not exceeded at any individual facility.

TABLE C-12

ESTIMATE OF EXCESS CANCER CASES OVER 70 YEARS FROM HAZARDOUS WASTE COMBUSTORS - BOILERS AND FURNACES

Pollutant	Type of Waste[c]	Control Device Performance			
		Base Case[a]		Pessimistic[b]	
		Baseline	After Regulation	Baseline	After Regulation
POHCs	Base Case	1	0	3	0
PICs		1	0	1	0
Metal		16	15	16	15
Total		18	15	20	15
POHCs	High Risk	25	2	55	2
PICs		4	0	8	0
Metals		582	292[d]	595	301[e]
Total		611	294[d]	658	303[e]

SOURCE: Reference 3, Exhibits 7-5, 7-8, 7-11, and 7-13.

[a] "Base case" assumes "typical" removal efficiencies for control devices.

[b] "Pessimistic" assumes removal efficiencies of control devices for toxic metals and hydrogen chloride are several percentages points lower than in the base case in most cases. For organic compounds, the difference is several fractions of a percent in most instances.

[c] See Footnote 5 on page C-28 for description of types of waste.

[d] Includes 74 cases from the burning of displaced wastes.

[e] Includes 85 cases from the burning of displaced wastes.

TABLE C-13

DISTRIBUTION OF MEI FROM HAZARDOUS WASTE COMBUSTORS - BOILERS AND FURNACES

MEI	Type of Waste[c]	Control Device Performance			
		Base Case[a]		Pessimistic[b]	
		Baseline	After Regulation	Baseline	After Regulation
$>1 \times 10^{-4}$	Base Case	0	0	0	0
1×10^{-4}		0	0	0	0
1×10^{-5}		10	6	10	6
1×10^{-6}		61	48	65	48
1×10^{-7}		103	56	101	72
$<1 \times 10^{-7}$		778	650	777	634
Total		952	759[d]	952	759[d]
$>1 \times 10^{-4}$	High Risk	0	0	0	0
1×10^{-4}		19	0	21	0
1×10^{-5}		100	73	102	73
1×10^{-6}		167	52	167	58
1×10^{-7}		198	35	207	36
$<1 \times 10^{-7}$		468	595	456	585
Total		952	755[d]	953	752[d]

Note: Numbers in table indicate the numbers of hazardous waste combustors associated with each maximum exposed individual risk level.

SOURCE: Reference 3, Exhibits 7-6, 7-9, 7-12, and 7-14.

[a] "Base case" assumes "typical" removal efficiencies for control devices.

[b] "Pessimistic" assumes removal efficiencies of control devices for toxic metals and hydrogen chloride are several percentages points lower than in the base case in most cases. For organic compounds the difference is several fractions of a percent in most instances.

[c] See Footnote 5 on page C-28 for description of types of waste.

[d] Difference in total device due to some devices that discontinue burning due to the regulations.

incinerators are estimated to pose a risk of 1 x 10^{-5} to the MEI under baseline conditions.

After compliance with the proposed rule, which would require control of emissions such that the maximum individual risk at any facility is no greater than 1 x 10^{-5}, EPA conservatively estimates that the annual cancer incidence for these metals could be reduced from 0.03 to 0.02, or a reduction of approximately one lifetime cancer case in a 70-year period. The risk reduction may be understated as the actual environmental protection afforded by the recommended control technologies at each affected facility could be higher.

Boilers/Furnaces. Assuming base case waste composition and base case control device performance, 18 excess cancer cases are estimated over the next 70 years from the baseline annual level of burning. If all devices were to burn high risk waste, baseline burning practices are predicted to cause 611 excess cancer cases over the next 70 years. Most of the cancer cases in both scenarios are attributable to metals emissions. After compliance with the proposed rule, the estimated excess cancer cases drop to 15 over 70 years for the base case wastes and to 294 over 70 years for the high risk waste. All 15 excess cancer cases after compliance are attributable to metals emissions, while 292 out of the 294 excess cancer cases are attributable to metal emissions after compliance under the high risk waste scenario. The pessimistic control device performance assumption has little effect on aggregate cancer cases when base case waste are assumed to be burned, but a slightly more pronounced effect when high risk wastes are assumed to be burned.

Maximum exposed individual risks were also calculated (see Table C-13). Of the 952 devices burning base case hazardous waste under baseline conditions, 10 are estimated to result in a MEI of 1×10^{-5}, 61 in a MEI of 1×10^{-6}, 103 in a MEI of 1×10^{-7}, and the remaining 778 devices in a MEI of less than 1×10^{-7}. Burning high risk waste increases the MEI and the number of devices estimated to pose higher MEI risk levels. For example, 19 devices are estimated to pose a 1×10^{-4} MEI when burning a high risk waste. After compliance, the number of devices for each of the MEI levels decreases with some control devices projected to discontinue the burning of hazardous wastes due to the regulations. The pessimistic control device performance assumption has little effect on the distribution of devices among the various MEI levels.

The analysis of human health risks from burning hazardous wastes is very uncertain and suffers from several important limitations. The major limits of the analysis include:

- The calculations suffer from the lack of information about key toxics such as hazardous waste composition, cancer potencies, and baseline control device performance. Some wastes being burned as fuel in boilers and industrial furnaces may be less contaminated than the base case waste and in other cases may be more contaminated than the base case. Therefore, the base case waste scenario will either overstate or understate risks for specific facilities.

- The analysis does not consider possible effects of clustering of devices in the same general locations. While such clustering would not affect aggregate cancer case estimates, the distribution of cancer risks across the population and to the MEIs would be altered.

- In calculating aggregate cancer cases from boilers and industrial furnaces, it is assumed that wastes displaced from burning under the rule will be burned in certain kilns and industrial furnaces, and will present risks equal to the average for these devices. Net reductions in cases may be over- or understated depending on the accuracy of this assumption. No adjustments are made to reflect risks from displaced wastes when calculating the distribution of devices by MEI cancer risks and threshold ratios.

References

1. U.S. Environmental Protection Agency, Office of Solid Waste. Burning of Hazardous Waste in Boilers and Industrial Furnaces. Proposed rule and request for comment. 52 FR 16982. May 6, 1987.

2. U.S. Environmental Protection Agency, Office of Solid Waste. Draft Preamble for Hazardous Waste Incinerator Regulation. June 14, 1988.

3. U.S. Environmental Protection Agency, Office of Solid Waste. Regulatory Impact Analysis for Hazardous Waste Boilers and Industrial Furnaces. Draft.

Municipal Waste Combustors (MWCs)

(NOTE: The EPA is currently developing a revised New Source Performance Standard (NSPS) for MWC emissions. The new NSPS, which was proposed on December 20, 1989, does not contain estimates of cancer risk, although work associated with it did revise cancer risk estimates from previous efforts. The most recent risk estimates are shown in Table C-17 in comparison with the previous estimates. The newer risk estimates do not show the breakdown of risk by pollutant. For purposes of risk estimates presented in Appendix B, the individual pollutant risks reported in Table C-16 have been used, but have been cut in half to generally reflect the overall decrease in estimated risk from MWCs.)

The Environmental Protection Agency's (EPA) Office of Air Quality Planning and Standards has conducted a multipollutant risk assessment of air emissions from existing and projected/new MWCs (incinerators). Based on the results of this study, the Administrator determined that EPA will regulate MWC emissions through the development of a revised new source performance standards for municipal incinerators (Sections 111(b) and 111(d) of the Clean Air Act). There are three major types of MWCs: massburn, modular and refuse derived fuel (RDF). The number, type and capacity of both existing and projected MWCs are summarized in Table C-14. The pollutants evaluated in this risk assessment are summarized in Table C-15. Other pollutants were not evaluated due to the lack of emissions and health effects data. Since limited data were available on short-term emissions, the risk analyses focused on long-term health impacts. The estimated risks for existing MWC ranged from 2 to 40 cancer incidences per year with an estimated maximum individual risk (MIR) of 1 in 1000 (1×10^{-3}). The estimated risk for projected/new sources ranged from 2 to 20 cancer incidences per year with an MIR of 1 in 10,000 (1×10^{-4}).

As shown in Table C-14, the number and type of MWCs range from a relatively large number of small modular facilities (average design capacity of 100 tons/day) to a small number of large capacity

TABLE C-14

NUMBER AND CAPACITY OF EXISTING AND PROJECTED MWCs IN THE U.S.

DESIGN TYPE	EXISTING MWCs		PROJECTED MWCs	
	NO. MWCs	CAPACITY (METRIC TONS/ DAY)	NO. MWCs	CAPACITY (METRIC TONS/ DAY)
A. MASSBURN				
- No heat recovery	21	13,000	0	0
- With heat recovery	24	20,100	118	113,000
B. MODULAR				
- No heat recovery	17	600	0	0
- With heat recovery	39	3,900	24	5,000
C. RDF				
- With heat recovery	10	11,400	31	39,000
D. UNKNOWN	0	0	37	36,000
E. TOTAL	111	49,000	210	193,000

SOURCE: Reference 2, pages 15 and 18.

TABLE C-15

POLLUTANTS EVALUATED IN MUNICIPAL WASTE COMBUSTOR RISK ASSESSMENT

Arsenic

Beryllium

Cadmium

Chlorobenzenes

Chlorophenols

Chromium^{+6}

Chlorinated Dibenzo-p-dioxins and Chlorinated Dibenzofurans (CDD/CDF)[a]

Formaldehyde

Hydrogen chloride

Lead

Mercury

Polychlorinated biphenyls (PCB)

Polycyclic aromatic hydrocarbons (PAH)

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[a] The terms dioxins and dibenzofurans refer to a group of 75 chlorodibenzo-p-dioxin compounds and 135 chlorodibenzofuran compounds, each having similar chemical and physical properties.

RDF facilities with an average design capacity of 1140 tons/day. The projected/new MWC facilities are expected to be similar in size except for the modular units which, on average, are expected to double in size. Due to the limited number of existing facilities and because the data base contained the stack parameters and control technology status necessary for a risk analysis, a detailed risk assessment was conducted for the existing sources. Model plant data were used to estimate risk from the projected/new MWC facilities. The Human Exposure Model was run for each existing facility and for the model plants using average emissions factors based primarily on available U.S. emission test data. Emission factors varied by design type and for existing and projected facilities. The analysis considered the cancer risk impacts for existing control levels and regulatory requirements (see Table C-16). Annual incidence was estimated to be from 4 to 60 and maximum individual risk levels from 10^{-3} to 10^{-4}. The risks from MWCs are dominated by the dioxin emissions. In most cases, over 90 percent of the estimated risk is from dioxin/furans.

There are significant uncertainties effecting this analysis. There are a wide range of emissions data found in the MWC data base, with average emission estimates used in this analysis. The feed material are heterogeneous and vary from day to day, season to season. The thirteen pollutants considered in this analysis are only a small portion of the total air emissions from MWCs, therefore the risks from this portion of emissions are not known and not represented in this risk analysis. Also, there is significant uncertainty in dioxin emissions due to variability in stack sample recovery results (from 10 to 100% reported pollutant recovery) and homolog versus isomer specific

TABLE C-16

RANGES IN THE CONTRIBUTION OF MWC EMISSION CONSTITUENTS TO ESTIMATED ANNUAL CANCER INCIDENCE AND MAXIMUM INDIVIDUAL LIFETIME CANCER RISK

Pollutant	Existing MWC Annual Cancer Incidence[a,d]	Existing MWC Maximum Individual Risk Range[b,e]	Projected MWC Annual Cancer Incidence[a,d]	Projected MWC Maximum Individual Risk Range[b,e]
Chlorinated dioxins and dibenzofurans (CDD/CDF)	2 to 40	10^{-6} to 10^{-3}	0.8 to 20	10^{-6} to 10^{-4}
Chlorophenols	0.0001 to 0.0003	10^{-9} to 10^{-8}	0.0001 to 0.0003	10^{-10} to 10^{-9}
Chlorobenzenes	0.009 to 0.02	10^{-7} to 10^{-6}	0.004 to 0.01	10^{-9} to 10^{-7}
Formaldehyde	0.009	10^{-8}	0.02	10^{-8} to 10^{-7}
Polycyclic aromatic hydrocarbons	0.01 to 0.6	10^{-7} to 10^{-5}	0.05 to 3.0	10^{-7} to 10^{-5}
Polychlorinated biphenyls	0.02	10^{-8} to 10^{-5}	0.2	10^{-9} to 10^{-6}
Arsenic	0.2	10^{-7} to 10^{-4}	0.1	10^{-8} to 10^{-7}
Beryllium	0.02	10^{-9} to 10^{-6}	0.001	10^{-11} to 10^{-8}
Cadmium	0.2	10^{-6} to 10^{-4}	0.2	10^{-7} to 10^{-6}
Chromium (hexavalent)	0.2	10^{-7} to 10^{-4}	0.1	10^{-7} to 10^{-6}
Rounded Total:[c]	2 to 40	10^{-6} to 10^{-3}	2 to 20	10^{-6} to 10^{-4}

SOURCE: Reference 2, p. 88.

[a] The ranges in annual cancer incidence reflect assumptions made regarding the potential carcinogenicity of classes of organic compounds.

[b] The ranges in maximum individual lifetime cancer risk reflect differences in emissions and the evaluation of emissions from MWC technologies within the existing and proposed categories.

[c] Apparent errors in totals are due to intentional rounding to one significant figure.

[d] Annual cancer incidence is defined as the average number of excess cancer cases expected annually in the exposed population.

[e] Maximum individual risk is defined as the probability of developing cancer following a lifetime exposure to the maximum modeled long-term ambient air concentration. The probability is expressed as a negative exponent of 10. A risk of 1 excess cancer in 10,000 population is expressed as 10^{-4}.

analysis. The variability in the dioxin emissions are the primary source of the range in risks from MWCs.

The evaluation of stack emissions from MWCs was limited to pollutants for which emission test data were available and some indication of public health or welfare were reported. Data were sufficient for analysis of 13 pollutants or classes of pollutants as summarized in Table C-15. On a total mass basis, the predominant emissions are carbon monoxide, hydrogen chloride, nitrogen oxides, and sulfur oxides.

As part of the original effort associated with the proposed MWC NSPS for new facilities (111b) and emission guidelines for existing facilities (111d), a risk assessment for baseline emissions from MWCs was conducted. This assessment used recently developed emissions data in conjunction with 17 model plants representing existing MWC (111d) facilities and 10 model plants representing new (111b) facilities to estimate cancer risks from direct inhalation exposure. A comparison of the baseline risks developed for the proposed NSPS and emission guidelines and the previous 1987 study are presented in Table C-17. As seen in Table C-17, the new estimates reduce estimated annual incidence between 25 and 50 percent.

References

1. Morrison, R., U.S. Environmental Protection Agency, Pollutant Assessment Branch. Municipal Waste Combustion (MWCs). September 7, 1988. 8 pages.

2. U.S. Environmental Protection Agency. Office of Solid Waste and Emergency Response. Municipal Waste Combustion Study: Report to Congress. EPA-530-SW-87-021a. June 1987.

TABLE C-17

MUNICIPAL WASTE COMBUSTOR BASELINE RISK ESTIMATES

	Old Estimate (1987)[a]	New Estimate (1989)[a]
New MWCs [111(b)]		
Annual Incidence	2 to 20	1 to 5
MIR	10^{-4} to 10^{-6}	10^{-5}
Existing MWCs [111(d)]		
Annual Incidence	2 to 40	1 to 15
MIR	10^{-3} to 10^{-6}	10^{-4}

SOURCE: Personal communication. Ray Morrison, U.S. EPA, Pollutant Assessment Branch.

[a] Only direct inhalation.

Municipal Solid Waste Landfills

Regulations are being proposed to control air emissions from municipal solid waste landfills under the Clean Air Act. New source performance standards are being developed under Section 111(b) for newly constructed landfills. Emission guidelines are being developed under Section 111(d) for existing landfills. The emission guidelines will be implemented by the States through plans approved by EPA.

Municipal solid waste landfill emissions are a complex aggregate of compounds. The gas that is generated from the decomposition of waste consists of approximately 50 percent methane, 50 percent CO_2, and trace constituents of non-methane organic compounds (NMOCs). Public health and welfare concerns are from NMOCs--which are composed of volatile organic compounds, some of which are toxic; and methane emissions which contribute to global warming and can cause explosions at or near landfills. The proposed regulations would set an annual emission cutoff for NMOCs, that when controlled at affected landfills, would reduce the bulk of the NMOCs, toxics, and methane emissions.

Best Demonstrated Technology (BDT) consists of an active gas collection system and an add-on control device as applied to landfills emitting large quantities of emissions. The add-on control device required at a minimum is a flare. The regulation would also encourage the use of energy recovery devices such as boilers, internal combustion engines, and gas turbines.

A background information document for the proposal is being revised and should be available by the end of the 1990. A copy of the document can be obtained by contacting Alice Chow, EPA/OAQPS at FTS 629-5626 or (919) 541-5626 or Mark Najarian, EPA/OAQPS at FTS 629-5393 or (919) 541-5393.

Publicly Owned Treatment Works (POTWs)

Estimates of emissions from publicly owned treatment works (POTWs) were developed as part of the NESHAP development program. POTWs were identified as significant emitters of potentially hazardous air pollutants (PHAPs) during the source assessment work for the individual pollutants. Data collected by the Office of Water Regulations and Standards were used to identify industries discharging PHAPs to POTWs. Site-specific loadings and model plant loadings were combined to generate the current industrial loadings at 1,621 POTWs, which treat 97 percent of all industrial wastewater. The TSDF aerated tank models were incorporated into a computer program that estimated emissions at each of the 1,621 POTWs. The Human Exposure Model was then used to develop risk estimates.

Results. Risk estimates were estimated for seven pollutants (see Table C-18). These pollutants are acrylonitrile, carbon tetrachloride, chloroform, ethylene dichloride, methylene chloride, perchloroethylene, and trichloroethylene. Total annual cancer risk from POTWs was estimated to be 1.5 cancer cases per year. Approximately one-quarter of this total was attributed to acrylonitrile (0.4 cancer cases per year). Three pollutants (trichloroethylene, methylene chloride, and chloroform) each were estimated to contribute 20 percent of the total, or 0.3 cancer cases per year for each pollutant. Maximum individual increased incidence was estimated to be 4.5×10^{-2}.

On a source category basis (see Table C-19), equipment manufacturers and the organic chemicals, plastics, and synthetic fibers industries were estimated to be the largest contributors to increased incidence at 0.51 and 0.44 cancer cases per year, respectively. This is approximately 63 percent of the total estimated cancer risk. The pulp

TABLE C-18

SUMMARY OF CANCER INCIDENCE FROM AIR TOXICS FROM POTWS

Pollutant	Emissions (Mg/yr)	Cancer Cases per year
Trichloroethylene	4,840	0.3
Perchloroethylene	3,230	0.07
Methylene chloride	2,130	0.3
Chloroform	439	0.3
Acrylonitrile	182	0.4
Ethylene dichloride	102	0.09
Carbon tetrachloride	47.9	0.03
Total	10,971	1.49

SOURCE: Reference 1.

TABLE C-19

SUMMARY OF CANCER INCIDENCE FROM AIR TOXICS FROM POTWs, BY SOURCE CATEGORY

Source Category	Number of Sites	Emissions, Mg/yr		Annual Cancer Cases
		Potentially Hazardous Air Pollutants	Total Hazardous Organics	
Equipment Manufacturing and Assembly	5,317	8,710	19,200	0.51
Hazardous Waste Treaters	641	312	1,676	0.059
Pulp and Paper Manufacturing	262	254	965	0.095
Organic Chemicals, Plastics, and Synthetic Fibers	424	248	3,970	0.44
Pharmaceutical Mfg.	87	179	680	0.084
Pesticides Mfg.	39	92.3	138	0.076
Electrical and Electronic Components Mfg.	267	34.7	798	0.0026
Electroplating and Metal Finishing	712	33.4	73.5	0.002
Industrial Laundries	~1,000	31.1	404	0.0023
Textile Mills	1,411	11.9	48.8	0.0158
Paint Manufacture and Formulation	518	10.3	35	0.0023
Leather Tanning and Finishing	150	1.61	85.3	0.00032
Petroleum Refining	45	1.35	331	0.001
Small Quantity Industrial Commercial, and Residential	24,177	1,060	6,570	0.019
Totals		10,980	34,975	1.48

SOURCE: Reference 1.

and paper industry and the pharmaceutical industry were estimated to be the next largest contributors to cancer risk from POTWs, each contributing approximately 6 percent of the total risk.

References

1. Memorandum. R.B. Lucas, U.S. EPA, Chemicals and Petroleum Branch, to J. Padgett, U.S. EPA, OAQPS. New Study on the Air Toxics Problem in the United States - POTW Emissions. July 29, 1988. 3 pages.

Radionuclides

Background. The EPA's Office of Radiation Programs (ORP) has evaluated radionuclides as a hazardous pollutant, based on the widespread human exposure to radionuclides in the ambient air, and on numerous studies that document the incidence of cancer resulting from exposure to ionizing radiation in many species of animals and human populations. Subsequently, EPA has listed radionuclides as hazardous air pollutants under section 112 of the Clean Air Act and has promulgated emission standards or work practices for seven categories of sources: (1) Department of Energy Facilities; (2) Nuclear Regulatory Commission-Licensed Facilities and Non-DOE Federal Facilities; (3) Elemental Phosphorous Plants; (4) Licensed Uranium Mill Tailings; (5) Underground Uranium Mines; (6) Uranium Fuel Cycle Facilities; and (7) Phosphogypsum Stacks.[6] Exposure to indoor concentrations of radon due to radon in soil gases entering homes through foundations and cellars was not included in this rulemaking.

Results to Date. The most recent estimates available on cancer risk due to exposure to radionuclide emissions to air are from a background information document in support of rules for radionuclides emissions to the air (see Reference 2). Table C-20 summarizes the cancer risk estimates from radionuclides and Table C-21 summarizes those from radon. As seen in these two tables, total estimated cancer incidence is approximately 4 fatal cancer cases per year. Maximum individual risks range from 7×10^{-6} to 4×10^{-3}.

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[6] Other sources that can contain and emit radionuclides include coal and oil combustion, drinking water aerators, municipal waste combustors, publicly owned treatment works, sewage sludge incinerators, Superfund sites, TSDFs, waste oil combustors, and woodstoves.

TABLE C-20

CANCER RISKS FROM RADIATION SOURCES EXCLUDING RADON

Source Category	Number of Sources	Maximum Individual Risk[a]	Fatal Cancers/yr	Population w/in 80 km
NRC-Licensees	6,000	2×10^{-4}	0.2	240,000,000
DOE Facilities	27	2×10^{-4}	0.3	67,000,000
High-Level Wastes[b]	0	*	*	*
Uranium Fuel Cycles	136	2×10^{-4}	0.1	240,000,000
Elemental Phos. Plants	8[c]	6×10^{-4}	0.07	1,800,000
Coal Fired Boilers	50,000[d] 1,200[e]	7×10^{-6} 3×10^{-5}	0.4 0.4	240,000,000
TOTALS			1.5[f]	

SOURCE: References 2 and 3.

[a] Maximum individual risk is for one facility; other facilities are estimated to have lower maximum individual risks. The maximum individual risk estimates for boilers are based on typical boilers and not individual boilers.

[b] There are no high-level waste disposal facilities operating in the U.S. (Reference 2, p. 5-1).

[c] Of these 8, five are operating and three are closed. Risk estimates based on operating plants only. Estimated maximum individual risk and fatal cancers per year for the three idle plants are 9×10^{-5} and 0.04, respectively.

[d] Industrial boilers (most of which are much smaller than utility boilers).

[e] Utility boilers.

[f] Based on Reference 3, total cancer effects (fatal plus nonfatal) would be approximately 3 cancer cases per year.

TABLE C-21

CANCER RISKS FROM RADON SOURCES

Source Category	Number of Sources	Maximum Individual Risk[a]	Fatal Cancers/yr	Population w/in 80 km
Underground Uranium Mines	15[b]	4×10^{-3} (1 site)	0.8	2,200,000
Open-Pit Uranium Mines	1,300[c]	5×10^{-5} (2 sites)	0.03	30,000,000
Uranium Mill Tailings (existing)	26[d]	3×10^{-5} (1 site)	0.0043	1,900,000
Disposal of Uranium Mill Tailings	50	3×10^{-4}	0.07	9,400,000
Radon from DOE Facilities	5	1×10^{-3} (1 sites)	0.07	28,000,000
Phospho-gypsum Stacks	66[e]	9×10^{-5} (2 sites)	1.0	95,000,000
TOTALS			2.0[f]	

SOURCE: References 2 and 3.

[a] The number of sites associated with the maximum individual risk is shown below the risk estimate in parentheses. Other facilities are estimated to have lower maximum individual risks. Number of sites for disposal of uranium mill tailings with this MIR was not identified.

[b] In 1982, there were 139 underground uranium mines in operation in the U.S. Currently, thirteen are producing ore and two are on standby.

[c] Over 1,300 surface uranium mines have been identified in the U.S. The risks are based on 265 mines, which account for over 99 percent of all surface uranium ore production; 2 are operating and the other 263 are closed or in varying states of reclamation.

[d] Of these 26, four are operating, eight are on stand-by, and 14 are being or have been discontinued. Cancer risks based on the twelve operating and stand-by facilities for operating and standby phases only.

[e] Of the 66 identifiable phosogypsum stacks, 63 are addressed in this assessment.

[f] Based on Reference 3, total cancer affects (fatal plus non-fatal) would be approximately 2.1 cancer cases per year.

Sources of Uncertainty. Source term measurement errors are not considered significant compared to other uncertainties.

Atmospheric dispersion models are a major source of uncertainty. Studies have indicated that an uncertainty of approximately a factor of about 2 for locations within 10 kilometers of the release point can be expected for estimates of annual average concentrations.

Dose estimates based on unit concentrations of radionuclides are a major source of uncertainty. Much of this uncertainty reflects real differences in individual characteristics within the general population. Dose estimates should be accurate within a factor of three or four.

Risk estimate uncertainties are believed to be within a factor of three of the true value. Risk estimates are continually being re-evaluated as new information becomes available.

References

1. U.S. EPA, Office of Radiation Programs. Risk Assessment Methodology. Environmental Impact Statement. NESHAPs for Radionuclides. Background Information Document - Volume 1. EPA 520/1-89-005. September 1989.

2. U.S. EPA, Office of Radiation Programs. Risk Assessments. Environmental Impact Statement. NESHAPs for Radionuclides. Background Information Document - Volume 2. EPA 520/1-89-006-1. September 1989.

3. U.S. Environmental Protection Agency. National Emission Standards for Hazardous Air Pollutants; Radionuclides. Final rule and notice of reconsideration. 54 FR 51654. December 15, 1989.

Sewage Sludge Incinerators

On an annual basis, approximately 1.7 million dry metric tons of sludge are estimated to be incinerated in 282 sludge incinerators at 169 publicly owned treatment works (POTWs) in the United States. The incineration of sewage sludge is regulated under the Clean Air Act, the Resource Conservation and Recovery Act, the Clean Water Act, and the Toxic Substances Control Act. Sewage sludge incinerators use wet scrubbing systems to control emissions. These systems have been designed primarily to control particulate emissions to meet both Federal and State requirements.

The Office of Water, U.S. EPA, proposed standards on February 6, 1989, (54 FR 5746) that would control seven toxic metals and total hydrocarbons from sewage sludge incinerators (see Table C-22). As part of this regulatory work, the Office of Water estimated both cancer and noncancer risk. The unit risk values for cancer risk were estimated based upon work completed by the U.S. EPA Carcinogen Assessment Group (CAG). The risk assessment considers only exposure due to inhalation.

In brief, the methodology used to estimate risk combined site-specific treatment plant data with air dispersion information for ten sites that serve as model facilities. Each POTW was assigned to one of the 10 model incinerators. Although these model facilities served as the basis for the fate and transport modeling, individual characteristics (e.g., volume of sludge incinerated daily) of each incinerating POTW were used in the risk analysis. One facility in each of the 10 groups of incinerators was modeled to determine its air dispersion characteristics by using the Industrial Source Complex Long-Term (ISCLT) model supplemented by LONGZ model and the COMPLEX I model to account for terrain effects in urban and rural settings,

TABLE C-22

POLLUTANTS FROM SEWAGE SLUDGE INCINERATORS FOR WHICH STANDARDS HAVE BEEN PROPOSED

Pollutant	Carcinogen (C)/Noncarcinogen (NC)
Arsenic	C
Beryllium	C
Cadmium	C
Chromium	C
Lead[a]	C
Mercury	NC
Nickel	C
Total Hydrocarbons[b]	C, NC

[a] Lead has recently been designated as a B_2 carcinogen.

[b] Includes both carcinogens and noncarcinogens. Carcinogenic hydrocarbons include such compounds as carbon tetrachloride, vinyl chloride, and PCB's.

respectively. Population data for each of the facilities were generated from the Human Exposure Model (HEM).

The results of the risk analysis showed that, under current conditions, exposure to seven metals and total hydrocarbon emissions from sewage sludge incinerators results in a projected upper bound estimate of 13 cancer cases per year and a maximum individual risk (MIR) of 5×10^{-2} summed across all pollutants. Most of the annual cancer incidence is projected to result from exposure to cadmium (see Table C-23). However, adjusting the unit risk factors to those reported in Table 2-6 of this report results in an estimated 37 cancer cases per year, with most of the annual incidence attributed to vinyl chloride. This occurs because the unit risk factor for vinyl chloride is approximately 10 times larger than that used in the sewage sludge incinerator study.

The estimates of risk from sewage sludge incinerators are especially sensitive to the assumptions made concerning the metal removal efficiencies of the scrubbers, and the percent of chromium emissions that is hexavalent. Other factors affecting the risk estimates include: (1) the assumption that all particulate emissions remain airborne (thus maximizing their potential for inhalation by the maximum exposed individual) and (2) the constituent concentrations in the sewage sludge being incinerated. The constituent concentration data used in the analysis are believed to underestimate the content of organic pollutants and to overestimate the content of metal pollutants in the sewage sludge. This uncertainty is due to the fact that the data on the sewage sludge used in the risk assessment were collected prior to the implementation of many pretreatment programs. Pretreatment programs that are available for a limited number of metals may lower the

TABLE C-23

ESTIMATED CANCER INCIDENCE BY POLLUTANT FOR SEWAGE SLUDGE INCINERATORS

Pollutant	Cancer Cases Per Year
Arsenic	0.17
Beryllium	<0.01
Cadmium	3.3
Chromium	0.26
Nickel	0.28
Total Hydrocarbons	8.6
Acrylonitrile	0.98
Aldrin	0.02
Benzene	0.09
Benzidine	0.26
Benzo(a)pyrene	1.52
Bis(chloromethyl)ether	0.25
Chlordane	0.15
Chloroform	0.10
Chloromethane	0.01
Chloromethyl methyl ether	0.01
Dibenzo(a,b)anthracene	0.06
1,2-Dibromo-3-chloropropane	0.05
Dieldrin	0.01
Diethylstilbestrol	0.56
Heptachlor epoxide	0.01
2,3,7,8 Hexachloro-dibenzo-p-dioxin	0.01
3-Methylcholanthrene	0.01
2-Nitropropane	0.25
N-Nitrosodiethylamine	0.17
N-Nitrosodimethylamine	0.06
PCBs	0.76
2,3,7,8-Pentachlorodibenzo-p-dioxin	0.29
Reserpine	0.01
2,3,7,8-Tetrachlorodibenzofuran	0.08
2,3,7,8-Tetrachlorodibenzo-p-dioxin	0.02
Other tetrachlorodibenzo-p-dioxin	0.02
Tetrachloroethylene	0.10
Vinyl chloride	2.7[a]
TOTAL	13

SOURCE: Reference 1, p. 7-55.

[a] Adjusting this estimate to the unit risk factor reported in Table 2-6 of this report results in an estimate of 27 cancer cases per year from vinyl chloride, for a total of 37 cancer cases per year from sewage sludge incinerators.

concentrations of these metals in sewage sludge. On the other hand, the Domestic Sewage Sludge Exclusion of RCRA may channel more organic wastes into municipal sewers as limits are imposed on the land disposal of hazardous wastes, particularly liquid wastes, thereby increasing the concentration of organic pollutants in municipal sewage sludge.

References

1. U.S. Environmental Protection Agency. Human Health Risk Assessment for Municipal Sludge Disposal: Benefit of Alternative Regulatory Options.

2. U.S. Environmental Protection Agency. Standards for the Disposal of Sewage Sludge. Proposed Rule. 54 FR 5746. February 6, 1989.

Superfund Sites

As of May 1988 there were 800 Superfund sites listed on the National Priorities List (NPL). Approximately 20 percent of these sites were placed on the NPL because of a high air score on the Hazard Ranking System (HRS). This means that the site had observed air releases that were significantly above background concentration. In addition, there have been estimates that approximately 40 to 60 percent of the sites on the NPL have a significant air component that must be considered either as a result of disturbing the site to implement a remedy or implementing the selected remedy itself (e.g., air stripping, incinerator, or soil vapor extraction). For many of these sites, the air emissions would include a variety of potentially toxic air pollutants.

Each Superfund site is unique as to the mix of air toxics that may be released. This uniqueness is due to the fact that the types of air toxics released depends on the type of hazardous materials located at the site, which will vary from one site to the next. Most of the air toxics data obtained has been the identification of the type of hazardous materials at individual sites that may result in the release of air toxics. Quantifying the levels of emissions has begun at a number off-sites. Thus, there are no national estimates of cancer risk from air toxics released from Superfund sites.

References

1. Memorandum. D. Dunbar, PEI Associates, Inc., to K. Meardon, Pacific Environmental Services, Inc. Superfund Material for Update Six Month Study. September 1, 1988. Attachment: Superfund Sites.

Treatment, Storage, and Disposal Facilities for Hazardous Waste

Background. Regulations to control organic air emissions as a class from hazardous waste treatment, storage, and disposal facilities (TSDFs) under Section 3004(n) of the Resource Conservation and Recovery Act (RCRA) were promulgated on June 21, 1990. These regulations apply to process vents and equipment leaks at TSDFs. Proposal of regulations that would apply to tanks, surface impoundments, and containers are scheduled for late 1990. A longer term effort is planned to address individual toxic constituent emissions as necessary to provide additional health protection.

Nationwide cancer incidence has been estimated through summing the results from a model that approximates the cancer incidence resulting from each individual facility and maximum lifetime cancer risk and acute and chronic non-cancer effects have been estimated using a model facility. A draft Background Information Document (BID) dated March 1988 was developed to support the proposal of standards. The BID provides a detailed review of the TSDF health risk assessment.

Results. The results of the health risk assessment for TSDF organic air emissions indicate that there are about 140 cancer incidences per year due to these emissions. Due to the large number of TSDF nationwide (over 2000 facilities) and the lack of site-specific data about these facilities, health risks have been estimated using models. Organic emissions have been calculated for each TSDF individually through a model that uses site-specific data where it is available and national averages for missing information. Cancer incidences associated with these emissions were calculated using a weighted average national cancer potency estimate. The weighted average potency was developed by weighing the national TSDF emissions of all non-carcinogens at a potency of zero with the national TSDF emissions of each carcinogen at its specific potency. The results of this analysis are summarized in Table C-24. While estimating site-specific emissions and potencies based on national average parameters causes a high degree of uncertainty for site-specific cancer incidence estimates, summing to a nationwide total yields a reasonable estimate of total cancer incidence.

The TSDF health risk assessment further shows that the maximum lifetime cancer risk to the most exposed individual is 2 in 100 (2×10^{-2}). Because the emission estimates for individual facilities that are calculated by the national emission model are highly uncertain, another analysis was used to calculate maximum cancer risk. Two model facilities were selected for analysis. The operation of these two facilities were then characterized in terms of the facility layout of waste management units and the types of wastes managed. Maximum risks for the two facilities were calculated through emission models and dispersion models identifying the maximum ambient concentration of organics. The same average potency used for calculating cancer incidence was used with the concentration to determine risk. The higher of the risks calculated for the two facilities was used as the maximum individual cancer risk. A major source of uncertainty in this assessment is the selection and characterization of the facilities used to estimate maximum risk and the use of the average potency.

The same two facilities that were used to calculate cancer risk were also used to assess non-cancer risks. Both short-term (acute) and long-term (chronic) non-cancer endpoints were compared to the ambient concentrations predicted for the two model facilities. The short-term concentration did not exceed any available level of concern and the long-term concentrations did not exceed available acceptable daily

TABLE C-24

EMISSIONS-WEIGHTED COMPOSITE UNIT RISK FACTOR (URF)

Chemical name (carcinogen)	LDR^a uncontrolled emissions, Mg/yr	URF	URF x emissions for chemical / Total TSDF emissions
1,1-dichloroethylene	1,093	5.0×10^{-5}	3.0×10^{-8}
1,2-diphenyl hydrazine	1	2.2×10^{-4}	8.8×10^{-11}
1,2-dibromoethane	0	2.2×10^{-4}	0
1,2-dibromo-3-chloropropane	2	5.0×10^{-3}	4.6×10^{-9}
1,2-dichloroethane	23,101	2.6×10^{-5}	3.3×10^{-7}
1,4-dioxane	270	1.0×10^{-6}	1.5×10^{-10}
2-nitropropane	8	3.0×10^{-3}	1.4×10^{-8}
acetaldehyde	6,214	2.2×10^{-6}	7.4×10^{-9}
acetonitrile	469.100		
acrylamide	74	1.0×10^{-3}	4.0×10^{-8}
acrylonitrile	17,770	6.8×10^{-5}	6.6×10^{-7}
aldrin	34	4.9×10^{-3}	8.9×10^{-8}
allyl chloride	248.600		
aniline	5,380	1.0×10^{-5}	2.9×10^{-8}
benzene	6154.000	8.0×10^{-6}	2.7×10^{-8}
benzotrichloride	21.653		
benzo(a)pyrene	2	1.7×10^{-3}	1.4×10^{-9}
benzo(b)fluoranthene	1.219		
benzylchloride	289.800		
benz(a)anthracene	0.230	8.9×10^{-4}	1.1×10^{-10}
bis(chloromethyl)ether	374		
bis(2-chloroethyl)ether	0	3.3×10^{-4}	0
bis(2-ethylhexyl)phthalate	338.062		
bromo-2-chloroethane	10.310		
butadiene	115	2.8×10^{-4}	1.8×10^{-8}
carbazole	46.760		
carbon tetrachloride	16,920	1.5×10^{-5}	1.4×10^{-7}
chlordane	8	3.7×10^{-4}	1.6×10^{-9}
chloroform	4,586	2.3×10^{-5}	5.7×10^{-8}
chloromethyl methyl ether	0	2.7×10^{-3}	0
chloronitrobenzene	2508.980		
chrysene	0.316		
creosote	17.110		
DDT	27	3.0×10^{-4}	4.5×10^{-9}
dibenz(a,h)anthracene	0.053	1.4×10^{-2}	4.0×10^{-10}
dichlorobenzene(1,4) (p)	0.085		
dichloropropene	30.540		
dimethoxy benzidine,(3,3')	0.000		
dimethyl phenol	21.310		
dimethyl sulfate	0.192		
dinitrotoluene	250.000	8.8×10^{-5}	1.2×10^{-8}
epichlorohydrin	1,595	1.2×10^{-6}	1.0×10^{-9}
ethyl acrylate	28.920		
ethyl carbamate	12.180		

(continued)

TABLE C-24

EMISSIONS-WEIGHTED COMPOSITE UNIT RISK FACTORS (URF) (concluded)

Chemical name (carcinogen)	LDR uncontrolled emissions, mg/yr	URF	URF × emissions for chemical / Total TSDF emissions
ethylene dibromide	10	2.2×10^{-4}	1.2×10^{-9}
ethylene imine (azaridine)	51640.000		
ethylene oxide	0.000	1.0×10^{-4}	0.000
formaldehyde	2,646	1.3×10^{-5}	1.9×10^{-8}
gasoline	2,742	6.6×10^{-7}	9.8×10^{-10}
heptachlor	1	1.3×10^{-3}	8.6×10^{-10}
hexachlorobenzene	158	4.9×10^{-4}	4.2×10^{-8}
hexachlorobutadiene	45780.000	2.2×10^{-5}	5.4×10^{-7}
hexachloroethane	1,553	4.0×10^{-6}	3.4×10^{-9}
hydrazine	238	2.9×10^{-3}	3.8×10^{-7}
indeno(123-cd)pyrene	0.033		
lead acetate	1.901		
lead subacetate	0.000		
lindane	9.5×10^{-5}	3.8×10^{-4}	2.0×10^{-14}
methyl chloride	58		
methyl cholanthrene (3)	5	3.0×10^{-3}	8.6×10^{-9}
methyl hydrazine	8		
methyl iodide	0.000		
methylene chloride	16,676	4.7×10^{-7}	4.3×10^{-9}
nitrobenzene	5438.900		
nitro-o-toluidine	0.000		
n-nitrosopyrrolidine	0.000	6.1×10^{-4}	0
n-nitroso-n-methylurea	0.000	8.6×10^{-2}	0
parathion	75.950		
pentachloroethane	2458.000		
pentachlorophenol	27.630		
phenylene diamine	1171.000		
polychlorinated biphenyls	0.061		
propylene dichloride	45.460		
styrene	582.499		
TCDD (tetrachlorodibenzo-p-dio)	0.310	33	5.6×10^{-6}
tetrachloroethane(1,1,1,2)	7,135	5.8×10^{-5}	2.3×10^{-7}
tetrachloroethylene	17,271	5.8×10^{-7}	5.4×10^{-9}
thiourea	5	5.5×10^{-4}	1.5×10^{-9}
toluene diamine	21.718		
toxaphene	56	3.2×10^{-3}	9.8×10^{-8}
trichloroethane(1,1,2)	18,458	1.6×10^{-5}	1.6×10^{-7}
trichloroethylene	56,353	1.7×10^{-6}	5.2×10^{-8}
trichlorophenol	30	5.7×10^{-6}	9.5×10^{-11}
vinyl chloride	626	4.1×10^{-6}	1.4×10^{-9}
Total nationwide uncontrolled emissions	1,839,267		8.6×10^{-6}

[a]LDR = Land disposal restrictions.

intake benchmark levels. The major source of uncertainty, beyond the uncertainty associated with the selection and characterization of the facility as noted above under cancer risk, is the characterization of the specific non-carcinogenic constituents and their concentrations.

References

1. U.S. EPA, OAQPS. Hazardous Waste TSDF - Background Information for Proposed RCRA Air Emission Standards. Volume I - Chapters. Preliminary Draft EIS. March 1988.

2. U.S. EPA, OAQPS. Hazardous Waste TSDF - Background Information for Proposed RCRA Air Emission Standards. Volume II - Appendices. Preliminary Draft EIS. March 1988.

Waste Oil Combustors

In 1985 estimates supplied by the Office of Solid Waste, about 638 million gallons of waste oil were combusted. Based on the available data, there are nine hazardous constituents in waste oil known to be emitted from combustion sources. Cancer risks were estimated for nine pollutants based on the availability of cancer potency estimates, while maximum concentration estimates were also estimated for the lead emissions (See Table C-25). Other known hazardous emissions such as formaldehyde are emitted from all oil combustion, but this study was designed to focus only on those pollutants that would be emitted at rates exceeding those found in virgin fuels. Therefore, the pollutants included in this study were those contaminants that were not normally found in virgin oils or those with waste oil concentrations higher than those typically found in virgin oils.

The emission factors for the ten pollutants studied were calculated from the typical level of these pollutants found in waste oil (Table C-26). These values were based on several sampling studies. Although virgin oil combustion generates very little or no bottom ash, typical waste oils will generate some bottom ash because not all the constituents in waste oil can be burned. Thus, assuming that 100 percent of the contaminants entering the boiler in the waste oil feed are emitted in the flue gas would overestimate emissions. Earlier studies provided enough data to estimate the partitioning and/or destruction efficiency for each pollutant of concern. Since waste oil is mostly burned in virgin oil combustion devices which are typically uncontrolled, it was assumed that no air pollution control devices were being used at any facility.

TABLE C-25

CANCER RISK ASSESSMENT RESULTS - WASTE OIL COMBUSTION

	METHOD 1 (based on 633 residual oil facilities)		METHOD 2 (based on 70 facilities known to burn waste oil)	
Pollutant	Maximum Individual Risk	Annual Incidence	Maximum Individual Risk	Annual Incidence
Arsenic	2.4×10^{-6}	0.48	1.6×10^{-4}	0.087
Cadmium	3.2×10^{-7}	0.064	2.1×10^{-5}	0.012
Chromium (+6)	3.2×10^{-8}	0.0065	2.1×10^{-6}	0.0012
Trichloroethylene	6.2×10^{-11}	0.000013	4.1×10^{-9}	0.0000022
Tetrachloroethylene	4.7×10^{-11}	0.0000096	3.1×10^{-9}	0.0000017
Benzene	8.3×10^{-10}	0.00017	5.4×10^{-8}	0.000030
Benzo(a)pyrene	2.3×10^{-9}	0.00047	1.5×10^{-7}	0.000085
Polychlorinated biphenyls	3.8×10^{-9}	0.00077	2.5×10^{-7}	0.00014
Total	2.7×10^{-6}	0.56	1.8×10^{-4}	0.10
Maximum Long-Term Lead Concentration	0.0047 μg/m³		0.33 μg/m³	

SOURCE: Reference 1, page 3.

TABLE C-26

POLLUTANT-SPECIFIC DATA USED IN THE WASTE OIL COMBUSTION CANCER RISK ASSESSMENT

Pollutant	Unit risk Factor[a]	Concentrations[b] Mean (75th %)	Range	Percent Emitted	Calculated Mean Emission Factor (lbs/10^{12} Btu)
Arsenic	4.3×10^{-3}	9(5)	0.9 - 94	70%	340
Cadmium	1.8×10^{-3}	5(10)	<0.2 - 49	40%	108
Chromium(+6)	1.2×10^{-2}	32(11)	0 - 571	31%	1.65
Lead	N/A	90(821)	0 - 4,730	64%	3100
Trichloroethylene	1.3×10^{-6}	539(370)	<1 - 4,000	0.1%	29
Tetrachloroethylene	5.8×10^{-7}	929(780)	<1 - 3,200	0.1%	51
Benzene	8.3×10^{-6}	1,129(200)	<3 - 55,000	0.1%	62
Benzo(a)pyrene	1.7×10^{-3}	8(12)	<1 - 17	0.1%	0.44
PCBs	1.3×10^{-3}	33(30)	0 - 3,150	0.1%	1.78

SOURCE: Reference 1, page 7.

[a] Units are in risk per lifetime exposure to 1 $\mu g/m^3$.
[b] Units are parts per million.

Two approaches were used in this study. The first approach used to assess waste oil combustion risks directly incorporated the results of the residual oil combustion analysis. This approach assumes each U.S. residual oil burner also combusts a proportionate amount of waste oil. Thus, OAQPS could reuse the existing dimensionless HEM residual oil results by making simple modifications to the Boiler Computer Model (BCM) to accommodate the different fuel rates and emission factors required to evaluate waste oil combustion emissions.

The second approach focused on those specific boilers that are known to burn waste oil. These combustors were identified by searching through an OAQPS data base (the National Emissions Data Systems or NEDS) to obtain a list of boilers burning waste oil. With this approach, each boiler required a HEM analysis (using the dimensionless emissions rates) and a BCM analysis to convert the HEM results to risk values. Since not all of the waste oil being burned in the U.S. was accounted for in those waste oil burners identified by OAQPS, the annual incidence results were scaled to national estimates by the ratio of sample waste oil use to national waste oil use. The estimated maximum individual risk associated with this sample of boilers was assumed to be representative of the entire population of waste oil units.

As can be noted in Table C-25, there is approximately two orders of magnitude difference between maximum individual risk estimates for the two approaches. Given that Approach 2 is based on actual reported quantities of waste oil burned, and that this risk statistic depends largely on site-specific characteristics, we believe that the results from Approach 2 are to be preferred. On the other hand, given the inherent uncertainties of the risk assessment process, the two approaches produce aggregate risk estimates that are quite similar (0.56

versus 0.10 cases/year). Because the NEDs data base is biased towards larger capacity units, which tend to produce lower estimates of risk per unit of fuel, the aggregate risk estimates from the first approach probably reflect more accurate estimates of national exposure.

Due to the nature of the risk assessment methodologies, an understanding of the uncertainties within the analysis is as important as the results. A brief summary of these uncertainties follows:

1. There are significant data gaps in our knowledge of the number and toxicity of pollutants being emitted from waste oil combustion. This study has included only those pollutants that have been measured in waste oil and are known as probable carcinogens.

2. Site-specific emissions and fuel contaminant level data were not available; average values were used.

3. The study assumes a steady-state condition in which fuel use patterns, control technology, and population remain constant over a period long enough to evaluate the cancer risk (a 70-year lifetime). It is certainly reasonable to expect that one or more of these parameters will change substantially over the study period.

4. The uncertainty in the estimates of carcinogenic potency is considerable. For the most part, unit risk estimates represent plausible upper bounds of the cancer risk. The estimates have been derived from studies of workers or test animals exposed to levels of the substances much higher than those found or modeled in the ambient air. It is not clear how applicable these exposures are to the lower concentrations of trace constituents present in the atmosphere due to waste oil combustion emissions. The aggregate cancer incidence estimates reflect the exposure of large numbers of people to low pollutant concentrations. In addition, cancer risks were evaluated for

each pollutant and total risks were calculated by adding individual pollutant risks. Synergistic or antagonistic effects that may be associated with complex mixtures of pollutants have not be calculated.

5. Only cancer risks have been estimated. Although this represents an important portion of the health concern about such mixtures, the possibility of other health effects was not examined.

6. There is a potential for exposure by routes other than direct inhalation. Although few data are available to estimate the relative contribution to exposure from the deposition and subsequent re-suspension or ingestion of emitted compounds, some affect on soil and water levels and subsequent exposure would be expected.

7. There are numerous simplifying assumptions in exposure assessment. The estimation of human exposure requires simplifying assumptions about the dispersion of the pollutants such as assumptions about terrain features (assumed flat terrain) at each boiler site and the use of the nearest meteorological data site as representative of the study area. Maximum individual lifetime risk is particularly sensitive to changes in such assumptions. Further, exposures beyond 50 kilometers were not examined.

Based on the above uncertainties within this analysis, we believe that this study does not provide accurate, absolute estimates of public risk. The study results must be viewed as rough estimates with error bands in the range of orders of magnitude.

References

1. Peters, W.D. and Fegley, R. U.S. Environmental Protection Agency. Waste Oil Combustion Cancer Risk Assessment. Technical Staff Paper. October 1987.

Woodstoves

Many studies on woodstove emissions have been undertaken as a part of EPA's Integrated Air Cancer Project (IACP). The goals of the IACP are to (1) identify the principal airborne carcinogens, (2) determine which emission sources are major contributors of carcinogens to ambient air, and (3) improve the estimate of human exposure and comparative human cancer risk from specific air pollution emission sources (Reference 1). The initial phases of the IACP were aimed at quantifying carcinogens emitted from residential woodstoves and motor vehicles because data at that time indicated that these two sources made a significant contribution to the mutagenic activity of ambient air samples.

Initial IACP studies were conducted in Raleigh, NC, and Albuquerque, NM, two communities with relatively simple airsheds where a significant percentage of the homes use wood as the major heating fuel. These initial IACP studies emphasized field and laboratory evaluation to select sampling and analysis methodologies for a major field study initiated in Boise, ID, in the winter of 1986-87. These field studies were designed to simultaneously sample and characterize the emissions at the source, in the ambient air near to specific sources, and in the ambient air distant from the sources. Sampling indoors and outdoors of homes both with and without woodstoves was conducted to provide an indication of total human exposure.

Other studies on woodstove emissions conducted under the IACP or elsewhere have included examining (1) the mutagenicity of woodsmoke (References 2 and 7), (2) the chemical characteristics of respirable particulate matter (Reference 7), (3) the effect of photooxidation reactions and aging by itself on the mutagenic activity of woodsmoke (References 3 and 4), (4) the relative mutagenic activity of the gas-phase reactants and products compared to that of the particulate phase (Reference 4), and (5) the relative mutagenicity and carcinogenicity of particle bound organics in woodsmoke with a variety of other sources of incomplete combustion products (References 5 and 6).

One study has estimated a unit risk factor of 1.0×10^{-5} for woodstove emissions (Reference 6). Combining relative potencies with the percentage organic extractable matter and particle emission rates suggests that woodstove emissions make a significantly greater contribution to ambient hazardous organics than the use of residential fuel oil on a mutagenic emission rate per joule of energy basis. More research is being undertaken to understand the relationship between the emissions, potential atmospheric transformations, human exposure, dosimetry, and final cancer risk from woodstove emissions as well as other sources of products of incomplete combustion.

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7. Watts, R.R., et. al. "Wood Smoke Impacted Air: Mutagenicity and Chemical Analysis of Ambient Air in a Residential Area of Juneau, Alaska," in APCA Journal, Vol. 38, No. 5, pp. 652-660. July 1988.

NONCANCER HEALTH RISK PROJECT

(Note: The following is the Executive Summary taken from Toxic Air Pollutants and Noncancer Health Risks: Screening Studies (U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, NC, 27711) Final External Review Draft. September, 1990. For additional information on the noncancer health risk project, contact Beth Hassett-Sipple, Pollutant Assessment Branch, (919)-541-5346.)

Greater than 2,000 man-made chemicals have been detected in ambient air. Many of these chemicals are known to cause adverse health effects in exposed humans or laboratory animals. Historically, the evaluation of risks associated with exposure to toxic air pollutants has focused on the potential for a carcinogenic response. In a recent Agency-wide comparison of environmental risks, noncancer risks associated with exposure to toxic air pollutant were among the Agency's highest concerns. To better understand the potential for the occurrence of adverse noncancer health effects as a result of exposure to routine emissions of toxic air pollutants, the Environmental Protection Agency (EPA) Office of Air Quality Planning and Standards (OAQPS) conducted the subject screening studies.

Approach

The screening studies represent approaches taken to characterize the potential noncancer risks associated with exposure to toxic air pollutants, each looking at slightly different aspects of the question. The initial phase included review of case reports; State, local, and Federal agencies' experiences; health effects literature; and exposure data (i.e., modeled and monitored ambient concentrations). From this information, two assessments were conducted by OAQPS: (1) an evaluation of the potential nationwide noncancer problem, and (2) a more complete analysis of a typical industrialized urban area.

Nature of the Problem

Several data sources were evaluated in the screening studies. These included: incidences of noncancer diseases in the United States; reports of noncancer effects linked with nonoccupational exposures to industrial air releases; and experiences of State, local, and Federal agencies involved in the regulation of toxic air pollutants. The data support the finding that adverse noncancer effects are an important public health concern and that environmental factors may play an important role in disease incidence. A survey of State, territorial, and local agencies indicated that a number of air releases, with the potential to result in serious noncancer health effects in the exposed population, are likely to occur each year. Many State and local air pollution control agencies have required additional air pollution control equipment for sources emitting toxic air pollutants specifically to reduce potential noncancer effects.

Available Exposure Data

An evaluation of available exposure data for toxic air pollutants revealed that air releases of these pollutants are widespread, but neither a comprehensive monitoring or modeling data base nor a complete toxicity data base exists. Biological indicators studied (e.g., human adipose and other tissue samples) revealed that many chemicals found in the atmosphere also have been detected in human tissues. Although other exposure pathways besides inhalation are expected to contribute to the presence of these chemicals in human tissue samples, air exposures can not be ignored.

OAQPS Analyses - Broad Screening and Urban County Studies

To examine the potential association between noncancer health effects and exposure to toxic air pollutants, two studies were undertaken by OAQPS. In both cases, data limitations precluded quantification of the magnitude of noncancer risks. However, the data do indicate ambient air concentrations of many pollutants may significantly contribute to potential noncancer health risks associated with environmental exposure.

The assessments were conducted by comparing modeled and/or monitored ambient concentrations to health reference levels and lowest-observed-adverse-effect levels (LOAELs).[7] The Broad Screening Study examined exposure to individual or multiple pollutants in ambient air based on exposure data from many areas of the country. Exposure data included ambient concentrations for approximately 325 pollutants monitored throughout the United States and annual averaged ambient modeled concentrations for approximately 40 pollutants emitted from more than 3,500 facilities. Health data and quantitative exposure data were available for only about 150 pollutants, less than ten percent of the chemicals which have been detected in ambient air. For those few chemicals with both health and exposure data, noncancer health risks appeared to be of concern. For approximately half of these chemicals, modeled and/or monitored levels exceeded health reference levels at numerous sites through the country. Ambient levels for approximately one-third of these chemicals exceeded the health reference level at more than 25 percent of the sites studies. Less than 5 percent of sites and chemicals indicated ambient concentrations exceeding LOAELs. These exceedances were seen with short-term and long-term ambient monitored concentrations. Modeling of short-term emissions was not performed because of data limitations.

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[7] Health reference level - The LOAEL divided by appropriate uncertainty factors to account for inter- and intra-species variability and identifies their LOAEL versus a NOAEL (no-observed-adverse-effect level).

LOAEL - In a study, the lowest dose or exposure level at which a statistically or biologically significant effect is observed in the exposed population compared with an unexposed control group. The study LOAEL was converted to an human equivalent level for comparison with exposure levels in the analyses conducted.

The simultaneous presence of several pollutants in ambient air is a frequent occurrence. When considering the potential impact of exposure to chemical mixtures, combined exposures were of concern for several types of health endpoints (e.g., reproductive/developmental toxicity, respiratory toxicity, etc.) in many geographical areas. The impacts of chemical mixtures were frequently dominated by a small subset of chemicals. For example, 15 chemicals associated with neurotoxic effects may have been monitored at one location though only two or three chemicals were monitored at concentrations that contributed significantly to health reference level exceedances.

The second analysis involved a more detailed evaluation of a midwestern industrialized urban county. This analysis expanded the number of chemicals evaluated in the Broad Screening Study and assessed the combined impact of multiple emission sources versus the impact of sources independently. Approximately 200 chemicals from 122 point sources plus 9 area sources were evaluated. Health reference levels and LOAELs were compared to modeled pollutant concentrations in three independent modeling exercises. Results suggested that a larger number of pollutants exceeded health reference levels for short-term modeled concentrations than for long-term modeled concentrations. Ambient concentrations were estimated to exceed health reference levels for long-term concentrations predicted by the Industrial Source Complex-Long Term model and the Human Exposure Model (4 and 8 percent of pollutants respectively) and short-term (24-hour) concentrations predicted by the

SCREEN model (22 percent of pollutants). Estimated long-term concentrations did not exceed any pollutant LOAELs. Estimated short-term (24-hour) concentrations exceeded LOAELs for approximately 2 percent of the pollutants assessed. In general, proximity to individual sources was a significant factor in determining degree of potential exposure. Another important finding of this study was that the additive contribution for a single pollutant emitted from a variety of sources resulted in health reference level exceedances over a broad geographic area.

Conclusions

Based upon analysis of the available data, it is clear that environmental exposures to toxic air pollutants have the potential to adversely impact public health. Although the magnitude of such noncancer risks can not be estimated from the available data, the broad implications of this study suggest that public health risks resulting from exposure to toxic air pollutants are not limited to carcinogenicity which has traditionally been the focus of regulatory programs. For certain pollutants, the combined impact of multiple sources may result in substantial exposure to many people. This finding suggests that the problem may not be limited to large point sources, but that smaller point sources and area sources that are numerous in populated areas can not be ignored. Similarly, exposure to chemical mixtures may result in adverse noncancer health risks that might not be predicted if only impacts of individual pollutants are considered.

The sparseness of available data represents the principal limitation of the screening studies. Few data were available to aid in the prediction of ambient concentrations and the derivation of health benchmarks. Despite the limitations, however, the studies support a finding that toxic air pollutants represent a potential noncancer health risk that warrants routine evaluation.

In recent Congressional activity to amend the Clean Air Act, the importance of adverse noncancer effects is emphasized. Many provisions of the proposed legislation focus on better understanding potential noncancer public health risks and controlling emissions of toxic air pollutants in order to reduce these risks.